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Hans A. Holter, Dirk Krueger, Serhiy Stepanchuk

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Center for Financial Studies | Goethe University Frankfurt | Grüneburgplatz 1 | 60323 Frankfurt am Main | Germany
Phone +49 69 798 30050 | Fax +49 69 798 30077 | info@ifk-cfs.de | www.ifk-cfs.de

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Center for Financial Studies | Goethe University Frankfurt | Grüneburgplatz 1 | 60323 Frankfurt am Main | Germany
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How Does Tax Progressivity and Household Heterogeneity Affect Laffer Curves?*

Hans A. Holter† Dirk Krueger‡ Serhiy Stepanchuk§

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Abstract: How much additional tax revenue can the government generate by increasing labor income taxes? In this paper we provide a quantitative answer to this question, and study the importance of the progressivity of the tax schedule for the ability of the government to generate tax revenues. We develop a rich overlapping generations model featuring an explicit family structure, extensive and intensive margins of labor supply, endogenous accumulation of labor market experience as well as standard intertemporal consumption-savings choices in the presence of uninsurable idiosyncratic labor productivity risk. We calibrate the model to US macro, micro and tax data and characterize the labor income tax Laffer curve under the current choice of the progressivity of the labor income tax code as well as when varying progressivity. We find that more progressive labor income taxes significantly reduce tax revenues. For the US, converting to a flat tax code raises the peak of the Laffer curve by 6%, whereas converting to a tax system with progressivity similar to Denmark would lower the peak by 7%. We also show that, relative to a representative agent economy tax revenues are *less* sensitive to the progressivity of the tax code in our economy. This finding is due to the fact that labor supply of two earner households is less elastic (along the intensive margin) and the endogenous accumulation of labor market experience makes labor supply of females less elastic (around the extensive margin) to changes in tax progressivity.

Keywords: Progressive Taxation, Fiscal Policy, Laffer Curve, Government Debt

JEL: E62, H20, H60

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†University of Oslo, hans.holter@nek.uu.se

‡University of Pennsylvania, CEPR and NBER. dkrueger@econ.upenn.edu

§École Polytechnique Fédérale de Lausanne. serhiy.stepanchuk@epfl.ch

1 Introduction

How much additional tax revenue can the government generate by increasing labor income taxes? That is, how far are we from the peak of the Laffer curve? Alternatively, and of special relevance given the recent explosion in public debt-to-GDP ratios, how much more public debt can the government sustain?

In this paper we provide quantitative answers to these questions, and argue that they are highly dependent on the *progressivity* of the tax code and on certain types of household heterogeneity. Since the shape of the labor income tax schedule varies greatly across countries[1], a fact which we document empirically in Section 2, Laffer curves are likely to be country-specific. In the last part of the paper we verify this claim by presenting a case study, comparing the Laffer curves for the U.S. and Germany.

In order to arrive at our conclusions, we develop an overlapping generations model with uninsurable idiosyncratic risk, endogenous human capital accumulation as well as labor supply decisions along the intensive and extensive margins. In the model households make a consumption-savings choice and decide on whether or not to participate in the labor market (the extensive margin), how many hours to work conditional on participation (the intensive margin), and thus how much labor market experience to accumulate (which in turn partially determines future earnings capacities).

We calibrate the model to U.S. macroeconomic, microeconomic wage, and tax data, but use country-specific labor income tax data, wage data and debt-to-output ratios when applying the model to Germany. For a given country we construct the Laffer curve by varying the *level* of labor income taxes, but holding their *progressivity* constant. Because of the cross-national differences in tax progressivity (and factors shaping household heterogeneity) the resulting Laffer curves will vary across countries.

The idea that total tax revenues are a single-peaked function of the level of tax rates

[1] We take the cross-country differences in tax progressivity, which might have emerged due to country-specific tastes for redistribution and social insurance, as exogenously given in this project.

dates back to at least Arthur Laffer. This peak and the associated tax rate at which it is attained are of great interest for two related reasons. First, it signifies the maximal tax revenue that a government can raise. Second, allocations arising from tax rates to the right of the peak lead to Pareto-inferior allocations with standard household preferences, relative to the tax rates to the left of the peak that generate the same tax revenue for the government. Thus the peak of the Laffer curve constitutes the positive and normative limit to income tax revenue generation by a benevolent government operating in a market economy, and its value is therefore of significant policy interest.

Trabandt and Uhlig (2011) in a recent paper characterize Laffer curves for the US and the EU 14 in the context of a model with an infinitely lived representative agent, flat taxes and a labor supply choice along the intensive margin. They find that the peak of the labor income tax Laffer curve in both regions is located between 50% and 70% tax depending on parameter values. The authors also show that the Laffer curve remains unchanged, with the appropriate assumptions, if one replaces the representative agent paradigm with a population that is ex-ante heterogeneous with respect to their ability to earn income and allows for progressive taxation. We here argue that in a quantitative life cycle model with realistically calibrated wage heterogeneity and risk, extensive margin labor supply choice as well as endogenous human capital accumulation, the degree of tax progressivity not only significantly changes the level and location of the peak of the Laffer curve for a given country, but also strongly affects the differences in that location *across countries*, relative to Trabandt and Uhlig (2011)'s analysis.

Why and how does the degree of tax progressivity matter for the ability of the government to generate labor income tax revenues in an economy characterized by household heterogeneity and wage risk? In general, the shape of the Laffer curve is closely connected to the individual (and then appropriately aggregated) response of labor supply to taxes. In his extensive survey of the literature on labor supply and taxation Keane (2011) argues that labor supply choices both along the intensive and extensive margin, life-cycle considerations and human capital accumulation are crucial modeling elements when studying the impact of taxes on labor supply. With such model elements present the *progressivity* of the labor income tax schedule can be expected to matter for the response of tax revenues to the *level* of taxes, although the magnitude and even the direction are not a priori clear.

There are several, potentially opposing, effects of the degree of tax progressivity on the response of tax revenues to the level of taxes. Keeping hours worked constant, with higher tax progressivity one can expect to collect more taxes from the high-earners and less taxes from the low-earners. However, one can also expect that changes in tax progressivity will affect hours worked. In a representative agent model, making the tax schedule progressive will reduce hours worked, due to an increase in the wedge the labor income tax creates in the household's intratemporal optimality condition (see Section 2). In a model with rich household heterogeneity, tax progressivity will have a differential impact on hours worked by high- and low-earners. First, increasing tax progressivity induces differential income and substitution effects on the workers in different parts on the earnings distribution (which we will illustrate in section 2). In addition, the presence of an extensive margin typically leads to a higher labor supply elasticity for low wage agents who are deciding about whether or not to participate in the labor market. A more progressive tax system with relatively low tax rates around the participation margin where the labor supply elasticity is high may in fact help to increase revenue if more agents decide to participate in the labor force.

In a life cycle model the presence of labor market risk will lead to higher labor supply elasticity for older agents due to a strong precautionary motive for younger agents, see Conesa, Kitao, and Krueger (2009). Because of more accumulated labor market experience, older agents have higher wages. Due to this effect a more progressive tax system may disproportionately reduce labor supply for high earners and lead to a reduction in tax revenue. Furthermore, when agents undergo a meaningful life-cycle, more progressive taxes will reduce the incentives for young agents to accumulate labor market experience and become high (and thus more highly taxed) earners. This effect will reduce tax revenues from agents at all ages as younger households will work less and older agents will have lower wages (in addition to working less). When human capital accumulation is modeled as years of labor market experience (learning by doing), as we do in Section 3, the life-cycle human capital effect is, however, counteracted by a greater short term benefit (higher net wages in the short run) from accumulating human capital. Thus the question of how the degree of tax progressivity impacts the tax level - tax revenue relationship (i.e. the Laffer curve) is a quantitative one, and the one we take up in this work.

We find, first, that the US could raise approximately 56% more tax revenue if the average tax rate is raised to 58%. Second, this peak of the Laffer curve (in terms of maximal tax revenues) rises by another 6% if the current tax code is replaced with a flat labor income tax, whereas converting to a tax system with progressivity similar to Denmark[2] would lower this peak by 7%[3]. Third, we show that, relative to a representative agent economy tax revenues are *less* sensitive to the progressivity of the tax code in our economy with household heterogeneity. This finding is primarily due to the fact that labor supply of two earner households is less elastic (along the intensive margin) and the endogenous accumulation of labor market experience makes labor supply of females less elastic (around the extensive margin) to changes in tax progressivity. Forth, we find that in simple infinite horizon and life-cycle economies, inequality modeled as variance in permanent ability or idiosyncratic shocks has little impact on the Laffer curve. Finally, we find that the U.S. can maximally sustain a debt level which is 330% of today's GDP through raising the labor income tax level and that this amount is decreasing in the progressivty of the tax schedule.

The paper by Trabandt and Uhlig (2011) has sparked new interest in the shape and international comparison of the Laffer curve. Another paper that computes this curve in a heterogeneous household economy very close to Aiyagari (1994) is the work by Feve, Matheron, and Sahuc (2013). In addition to important modeling differences their focus is how the Laffer curve depends on outstanding government debt, whereas we are mainly

[2]We find Denmark to have the most progressive taxes in the OECD.
[3]In Section 7 we find that the impact of progressivity is even larger in Germany.

concerned with the impact of the progressivity of the labor income tax code on the Laffer curve. Two closely related papers are also Guner, Lopez-Daneri, and Ventura (2014) and Badel and Huggett (2014). The focus of these papers is how much more revenue can be raised by starting from the current US tax system and making it more progressive. In line with our findings there is a limited potential for increasing revenues through increasing the progressivity of the tax system. Another related paper is Chen and Imrohoroglu (2013) who study the relationship between tax levels and the US debt. Finally, Kindermann and Krueger (2014) characterize the optimal top marginal tax rate in a model fairly similar to ours, but are not concerned with deriving Laffer curves for overall labor income tax revenue.

Our paper is structured as follows. In Section 2 we discuss our measure of tax progressivity and develop a progressivity index by which we rank OECD countries. In Section 3 we describe our quantitative OLG economy with heterogeneous households and define a competitive equilibrium. Section 4 is devoted to the calibration and country-specific estimation of the model parameters, and Section 5 describes the computational Laffer curve thought experiments we implement in this paper. The main quantitative results of the paper with respect to the impact of tax progressivity and household heterogeneity are presented in Section 6. Section 7 extends the analysis to Germany. We conclude in Section 8. The appendix discusses the transformation of a growing economy with extensive labor supply margin into a stationary economy, as well as details of the estimation of the stochastic wage processes from micro data.

2 Tax Progressivity in OECD Countries

Labor income taxes in the OECD are generally progressive and differ by household composition. To approximate country tax functions, we use the labor income tax function proposed by Benabou (2002) and also recently employed by Heathcote, Storesletten, and Violante (2012) who argue that it fits the U.S. data well.[4] Let y denote pre-tax (labor) income and

[4]see Appendix 9.3 for more details.

ya after tax income. The tax function is implicitly defined by the mapping between pre-tax and after-tax labor income:

$$ya = \theta_0 y^{1-\theta_1} \tag{1}$$

We use *labor income* tax data from the OECD to estimate the parameters θ_0 and θ_1 for different family types, under the assumption that married couples are taxed on their joint earnings. Table 4 in the Appendix summarizes our findings.

There are many ways to measure tax progressivity. We summarize the progressivity of the tax code by the following concept of the progressivity tax wedge between income y_1 and income $y_2 > y_1$:

$$PW(y_1, y_2) = 1 - \frac{1 - \tau(y_2)}{1 - \tau(y_1)} \tag{2}$$

where $\tau(y)$ is the average tax rate a household with income y pays. Wedge based measures of progressivity are common in the literature, for example, similar progressivity measures have been used by Guvenen, Kuruscu, and Ozkan (2009) and Caucutt, Imrohoroglu, and Kumar (2003). As long as the tax code is weakly progressive and thus $\tau(y_2) \geq \tau(y_1)$ this measure takes a value between 0 and 1. It is equal to zero for a proportional tax code for all income levels y_1 and y_2 and increases with the increase in the average tax rate τ as earnings increases from y_1 to y_2.

Guvenen, Kuruscu, and Ozkan (2009) define the tax progressivity wedge using the marginal tax rate function in place of $\tau(y)$. Using the average tax rate instead has the advantage[5] that in our tax function tax progressivity is uniquely determined by the parameter θ_1 and independent of the scale parameter θ_0, see Section 9.3. By varying θ_0 we can then increase the tax *level* while at the same time keeping tax progressivity (as measured by the wedge) constant for all levels of y_1 and y_2.

[5]Using the average tax function also makes the measure more robust. Guner, Kaygusuz, and Ventura (2012) show that the actual average tax function in the U.S. is approximated relatively well by a polynomial whereas the stepwise linear marginal tax function is not.

Table 1: Tax-Progressivity in the OECD 2000-2007

Country	Progressivity Index	Relative Progressivity (US=1)
Japan	0.101	0.74
Switzerland	0.133	0.97
Portugal	0.136	0.99
US	0.137	1.00
France	0.142	1.03
Spain	0.148	1.08
Norway	0.169	1.23
Luxembourg	0.180	1.31
Italy	0.180	1.31
Austria	0.187	1.37
Canada	0.193	1.41
UK	0.200	1.46
Greece	0.201	1.47
Iceland	0.204	1.49
Germany	0.221	1.61
Sweden	0.223	1.63
Ireland	0.226	1.65
Finland	0.237	1.73
Netherlands	0.254	1.85
Denmark	0.258	1.88

To obtain an index of tax progressivity across countries, we fit the tax function in equation (1) for singles without children[6] and married couples with zero, one and two children (the household types which we will have in the model in Section 3). We then take the sum of the estimated θ_1's weighted by each family type's share of the population in the U.S. Table 1 displays the progressivity index for the U.S., Canada, Japan, and all the countries in Western Europe.

We observe that there is considerable cross-country variation in tax progressivity in the OECD. As measured by the tax progressivity wedge Japan has the least progressive taxes, whereas the most progressive tax code can be found in Denmark. As measured by the index, taxes in Denmark are about 2.5 times more progressive than in Japan[7]. The U.S. is among

[6]In the model we assume that singles do not have children and that the maximum number of children is 2. We therefore give θ_1 for singles without children the population weight of all singles and θ_1 for married couples the population weight of married couples with 2 or more children. We use U.S. population shares to avoid conflating cross-county differences in tax progressivity with cross-country differences in family structures.

[7]In Section 6 below we find that countries raise more revenue and sustain more debt with flatter taxes. This is consistent with the observation that Japan not only has the flattest taxes in the OECD but also the

the countries with least progressive tax codes.

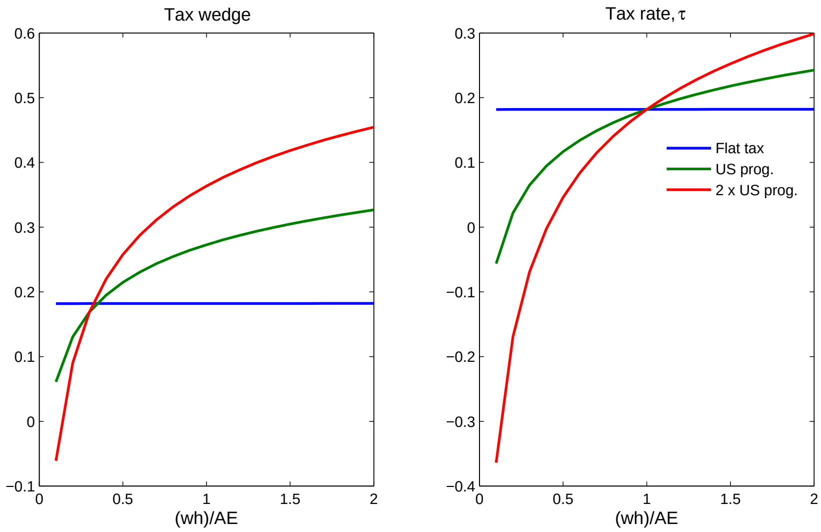

Figure 1: Changing tax progressivity

The right panel of figure 1 shows the average tax rate function that we obtain for U.S. singles (green line), plotted against labor earnings relative to average earnings, AE, and how it changes as we multiply θ_1 in that function by 0 (converting it to a flat tax) or by 2 (approaching the progressivity of the Danish tax system).

The entity that determines the distortionary effect of progressive taxes on labor supply is the *tax wedge*[8] in the households' intratemporal first order condition,[9] given by $\tau + \frac{wh}{AE}\tau'$. The left panel of figure 1 plots this tax wedge against labor earnings. As we discussed in section 1, changes in tax progressivity introduce opposite income and substitution effects on high- and low-earners. The right panel shows that increasing tax progressivity raises average tax rates and thus introduces a positive income effect on the hours worked of the high-earners, with the opposite effect on the low-earners. The left panel shows that the same

highest debt-to-GDP ratio.

[8]This is a different concept than the previously defined *tax progressivity wedge*, our summary measure of the progressivity of the tax code, and summarizes the distortions of the labor supply decisions from any labor income tax, progressive or not.

[9]With a flat labor income tax, the first-order condition which characterizes the choice of hours worked is given by $u'_c w(1-\tau) = -u'_h$, whereas with progressive taxation, it becomes $u'_c w(1 - \underbrace{(\tau + \frac{wh}{AE}\tau')}_{\text{tax wedge}}) = -u'_h$.

experiment raises the tax wedge, thereby introducing a negative substitution effect on the high-earners (as well as most of the workers), but has an opposite effect on the workers in the lowest part of the earnings distribution.

3 The Model

In this section we describe the model we will use to characterize the shape of the Laffer curve for different countries, and specifically discuss the model elements that sets our heterogeneous household economy apart from the representative agent model employed by Trabandt and Uhlig (2011).

3.1 Technology

There is a representative firm which operates using a Cobb-Douglas production function:

$$Y_t(K_t, L_t) = K_t^{\alpha} \left[Z_t L_t\right]^{1-\alpha}$$

where K_t is the capital input, L_t is the labor input measured in terms of efficiency units, and Z_t is the labor-augmenting productivity. The evolution of capital is described by:

$$K_{t+1} = (1 - \delta)K_t + I_t$$

where I_t is the gross investment, and δ is the capital depreciation rate. We assume that Z_t, the labour-augmenting productivity parameter, grows deterministically at rate μ:

$$Z_t = Z_0(1 + \mu)^t.$$

The production function and the accumulation of capital equation imply that on the balanced growth path, capital, investment, output and consumption will all grow at the same rate

μ[10]. For convenience, we will set $Z_0 = 1$. Each period, the firm hires labor and capital to maximize its profit:

$$\Pi_t = Y_t - w_t L_t - (r_t + \delta) K_t.$$

In a competitive equilibrium, the factor prices will be equal to their marginal products:

$$w_t = \partial Y_t / \partial L_t = (1-\alpha) Z_t^{1-\alpha} \left(\frac{K_t}{L_t} \right)^{\alpha} = (1-\alpha) Z_t \left(\frac{K_t / Z_t}{L_t} \right)^{\alpha} \tag{3}$$

$$r_t = \partial Y_t / \partial K_t - \delta = \alpha Z_t^{1-\alpha} \left(\frac{L_t}{K_t} \right)^{1-\alpha} - \delta = \alpha \left(\frac{L_t}{K_t / Z_t} \right)^{1-\alpha} - \delta \tag{4}$$

We restrict our analysis to balanced growth equilibria (in which long-run growth is generated by an exogenous technological progress). Following King, Plosser, and Rebelo (2002) and Trabandt and Uhlig (2011), we need to impose some restrictions on the production technology, preferences, as well as government policy functions that allow us to transform the growing economy into a corresponding stationary one, using straightforward variable transformation.

To start, along a balanced growth path (BGP) $K^z = K_t / Z_t$ will be constant. We furthermore define $w_t^z = w_t / Z_t$, and note that both w_t^z and r_t will also remain constant on the BGP, so we drop the time subscript for these variables as well.

3.2 Demographics

The economy is populated by J overlapping generations of finitely lived households. We model heterogeneity in family structure explicitly since in the data family type is an important determinant of the income tax code, something we wish to capture in our model. There are 5 types of households; single males, single females, and married couples with $x \in \{0, 1, 2\}$ children[11]. We assume that within the same married household, the husband and the wife

[10] See King, Plosser, and Rebelo (2002).

[11] In our model, children only influence the labor income tax code that a household faces. Given that family structure is exogenous and that we will assume logarithmic utility from consumption, modeling consumption needs of children explicitly via household equivalence scales would not change the household maximization problem.

are of the same age. All households start life at age 20 and enter retirement at age 65. We follow Cubeddu and Rios-Rull (2003) and Chakraborty, Holter, and Stepanchuk (2012) in modeling marriage and divorce as exogenous shocks. Let j denote the household's age. Single households face an age-dependent probability, $M(j)$, of becoming married whereas married households face an age-dependent probability, $D(j)$, of divorce. Single individuals who enter marriage have rational expectations about the type of a potential partner and face an age-dependent probability distribution, $\Xi(x, j)$, over the number of children in the household. Married households face age-dependent transition probabilities, $\Upsilon(x, x', j)$, between 0,1, and 2 children in the households. We assume for simplicity that single households do not have children and that children "disappear" when a divorce occurs.[12]

The probability of dying while working is zero; retired households, on the other hand, face an age-dependent probability of dying, $\pi(j)$, and die for certain at model age $J = 76$, corresponding to a real world age of 100. By assumption a husband and a wife both die at the same age. A model period is 1 year, so there are a total of 45 model periods of active work life. We assume that the size of the population is fixed (there is no population growth). We normalize the size of each new cohort to 1. Using $\omega(j) = 1 - \pi(j)$ to denote the age-dependent survival probability, by the law of large numbers the mass of retired agents of age $j \geq 65$ still alive at any given period is equal to $\Omega_j = \prod_{q=65}^{q=j-1} \omega(q)$.

In addition to age, marital status, and number of children, households are heterogeneous with respect to asset holdings, exogenously determined ability of its members, their years of labor market experience, and idiosyncratic productivity shocks (market luck). We assume that men always work some positive hours during their working age. However, a woman can either work or stay at home. Married households jointly decide on how many hours to work, how much to consume, and how much to save. Females who participate in the labor market, accumulate one year of labor market experience. Since men always work, they accumulate an additional year of working experience every period. Retired households make no labor

[12] Again, given our utility function the consumption requirements these children may have would not affect the household decision problem.

supply decisions but receive a social security payment, Ψ_t.

There are no annuity markets, so that a fraction of households leave unintended bequests which are redistributed in a lump-sum manner between the households that are currently alive. We use Γ_t to denote the per-household bequest.

3.3 Labor Income

The wage of an individual depends on the aggregate wage per efficiency unit of labor, w^z, and the number of efficiency units the individual is endowed with. The latter depends on the individual's gender, $\iota \in (m, w)$, ability, $a \sim N(0, \sigma_\iota^2)$, accumulated labor market experience, e, and an idiosyncratic shock, u, which follows an AR(1) process which is common to all individuals of the same gender (but of course the realization of this shock is not common to all households). Thus, the wage of an individual with characteristics (a, e, u, ι) is given by:

$$log(w^z(a, e, u, \iota)) = log(w^z) + a + \gamma_{0\iota} + \gamma_{1\iota} e + \gamma_{2\iota} e^2 + \gamma_{3\iota} e^3 + u \tag{5}$$

$$u' = \rho_\iota u + \epsilon, \quad \epsilon \sim N(0, \sigma_{\epsilon_\iota}^2) \tag{6}$$

$\gamma_{0\iota}$ here captures the gender wage gap. $\gamma_{1\iota}$, $\gamma_{2\iota}$ and $\gamma_{3\iota}$ capture returns to experience for women and the age profile of wages for men.

3.4 Preferences

We assume that married couples jointly solve a maximization problem where they put equal weight on the utility of each spouse. Their momentary utility function, U^M, depends on work hours of the husband, $n^m \in (0, 1]$, and the wife, $n^w \in [0, 1]$, and takes the following form:

$$U^M(c, n^m, n^w) = \log(c) - \frac{1}{2}\chi^{Mm}\frac{(n^m)^{1+\eta^m}}{1+\eta^m} - \frac{1}{2}\chi^{Mw}\frac{(n^w)^{1+\eta^w}}{1+\eta^w} - \frac{1}{2}F^{Mw} \cdot \mathbb{1}_{[n^w>0]} \tag{7}$$

where $F^{Mw} \sim N(\mu_{F^{Mw}}, \sigma_{F^{Mw}}^2)$ is a fixed disutility from working positive hours. The indicator function, $\mathbb{1}_{[n>0]}$, is equal to 0 when $n = 0$ and equal to 1 when $n > 0$. The momentary utility function for singles is given by:

$$U^S(c,n,\iota) = \log(c) - \chi^{S\iota}\frac{(n)^{1+\eta^\iota}}{1+\eta^\iota} - F^{S\iota}\cdot \mathbb{1}_{[n>0]} \tag{8}$$

We allow the disutility of work to differ by gender and marital status and the fixed cost of work for women to differ by marital status.

King, Plosser, and Rebelo (2002) show that in a setup with no participation decision, the above preferences are consistent with balanced growth. In the appendix, we demonstrate that this continues to hold with fixed disutility from working positive hours and operative extensive margin.

3.5 Government

The government runs a balanced social security system where it taxes employees and the employer (the representative firm) at rates τ_{ss} and $\tilde{\tau}_{ss}$ and pays benefits, Ψ_t, to retirees. The government also taxes consumption, labor and capital income to finance the expenditures on pure public consumption goods, G_t, which enter separable in the utility function, interest payments on the national debt, rB_t, lump sum redistributions, g_t, and unemployment benefits T_t. We assume that there is some outstanding government debt, and that the government debt to output ratio, $B_Y = B_t/Y_t$, is constant over time. Spending on pure public consumption is also assumed to be proportional to GDP so that, $G_Y = G_t/Y_t$ is constant. Consumption and capital income are taxed at flat rates τ_c, and τ_k. To model the non-linear labor income tax, we use the functional form proposed in Benabou (2002) and recently used in Heathcote, Storesletten, and Violante (2012):

$$ya = \theta_0 y^{1-\theta_1}$$

where y denotes pre-tax (labor) income, ya after-tax income, and the parameters θ_0 and θ_1 govern the level and the progressivity of the tax code, respectively.[13]. Heathcote, Storeslet-

[13] A further discussion of the properties of this tax function is provided in the appendix

ten, and Violante (2012) argue that this fits the U.S. data well. We fit family type specific tax schedules. In addition, the government collects social security contributions to finance the retirement benefits.

On a BGP with constant tax rates, the ratio of government revenues to output will remain constant. G_t, g_t, Ψ_t and T_t must also remain proportional to output.

We define the following ratios:

$$R^z = R_t/Z_t, \quad R^{ssz} = R_t^{ss}/Z_, \quad g^z = g_t/Z_t, \quad G^z = G_t/Z_t, \quad \Psi^z = \Psi_t/Z_t, \quad T^z = T_t/Z_t$$

where R_t are the government's revenues from the labor, capital and consumption taxes and R_t^{ss} are the government's revenues from the social security taxes. Denoting the fraction of women[14] that work 0 hours by ζ_t, we can write the government budget constraints (normalized by GDP) as:

$$g^z \left(45 + \sum_{j \geq 65} \Omega_j \right) + \frac{45}{2} T^z \zeta_t + G^z + (r - \mu) B^z = R^z$$
$$\Psi^z \left(\sum_{j \geq 65} \Omega_j \right) = R^{ssz}.$$

The second equation assures budget balance in the social security system by equating per capita benefits times the number of retired individuals to total tax revenues from social security taxes. The first equation is the regular government budget constraint on a balanced growth path. The government spends resources on per capita transfers (times the number of individuals in the economy), on unemployment benefits for women that work zero hours, on government consumption and on servicing the interest on outstanding government debt, and has to finance these outlays through tax revenue.

[14] Recall that we assume that men always work.

3.6 Recursive Formulation of the Household Problem

At any given time, a married household is characterized by $(k, e^m, e^w, u^m, u^w, a^m, a^w, x, j)$, where k is the household's savings, e^m and e^w are the husband's ("man") and the wife's ("woman") experience level, u^m and u^w are their transitory productivity shocks, while a^m and a^w are their permanent ability levels. Finally, x is the household's number of children and j is the household's age. Recall that we assumed that the male's experience is always equal to his age, $e^m = j$, and we can therefore drop e^m from the state space for married couples. The state space for a single household is (k, e, u, a, ι, j).

To formulate the household problem along the BGP recursively, we first define:

$$c_j^z = c_{t,j}/Z_t, \quad k_j^z = k_{t,j}/Z_t.$$

where $c_{t,j}$ and $k_{t,j}$ are the household's consumption and savings.

Since on the BGP the ratio of aggregate consumption and savings to output (and thus to Z_t) remains constant over time, we also conjecture that household-level c_j^z and k_j^z will not depend on calendar time, so that we can omit the time subscript for them as well. For the same reason, $\Gamma^z = \Gamma_t/Z_t$ will not change over time. We can then formulate the optimization problem of a married household recursively:

$$\begin{aligned} V^M(k^z, e^w, u^m, u^w, a^m, a^w, x, j) = &\max_{c^z,(k^z)',n^m,n^w} \Big[U\left(c, n^m, n^w\right) \\ &+ \beta(1 - D(j))E_{(u^m)',(u^w)',x'}\left[V^M((k^z)', (e^w)', (u^m)', (u^w)', a^m, a^w, x', j+1)\right] \\ &+ \frac{1}{2}\beta D(j)E_{(u^m)',(u^w)'}\left[V^S((k^z)'/2, u', a, m, j+1) + V^S((k^z)'/2, (e^w)', u', a, w, j+1)\right]\Big] \end{aligned}$$

s.t.:

$$c^z(1+\tau_c) + (k^z)'(1+\mu) = \begin{cases} \left(k^z + \Gamma^z\right)\left(1 + r(1-\tau_k)\right) + 2g^z + Y^L, & \text{if } j < 65 \\ \left(k^z + \Gamma^z\right)\left(1 + r(1-\tau_k)\right) + 2g^z + 2\Psi^z, & \text{if } j \geq 65 \end{cases}$$

$$
\begin{aligned}
Y^L &= \left(Y^{L,m} + Y^{L,w}\right)\left(1 - \tau_{ss} - \tau_l^M(x)\left(Y^{L,m} + Y^{L,w}\right)\right) + \left(1 - \mathbb{1}_{[n^w>0]}\right)T \\
Y^{L,\iota} &= \frac{n^i w^{z,\iota}\left(a^\iota, e^\iota, u^\iota\right)}{1 + \tilde{\tau}_{ss}}, \ \iota = m, w \\
(e^m)' &= j + 1, \quad (e^w)' = e^w + \mathbb{1}_{[n^w>0]}, \\
n^m &\in (0,1], \quad n^w \in [0,1], \quad (k^z)' \geq 0, \quad c^z > 0, \\
n^\iota &= 0 \quad \text{if } j \geq 65, \ \iota = m, w.
\end{aligned}
$$

Y^L is the household's labor income composed of the labor incomes of the two spouses, which they receive during the active phase of their life, τ_{ss} and $\tilde{\tau}_{ss}$ are the social security contributions paid by the employee and by the employer. The problem of a single household can be written:

$$
\begin{aligned}
V^S(k^z, e, u, a, \iota, j) = \max_{c^z, (k^z)', n} \Big[& U(c, n) \\
& + \beta(1 - M(j)) E_{u'}\left[V^S((k^z)', e', u', a, \iota, j+1)\right] \\
& + \beta M(j) E_{(k^z)', e^{-\iota}, (u^m)', (u^w)', a^{-\iota}, x'}\left[V^M((k^z)', (e^w)', (u^m)', (u^w)', a^m, a^w, x', j+1)\right]\Big]
\end{aligned}
$$

s.t.:

$$
c^z(1+\tau_c) + (k^z)'(1+\mu) = \begin{cases} (k^z + \Gamma^z)\left(1 + r(1-\tau_k)\right) + g^z + Y^L, & \text{if } j < 65 \\ (k^z + \Gamma^z)\left(1 + r(1-\tau_k)\right) + g^z + \Psi^z, & \text{if } j \geq 65 \end{cases}
$$

$$
\begin{aligned}
Y^L &= \left(Y^{L,\iota}\right)\left(1 - \tau_{ss} - \tau_l^S\left(Y^{L,\iota}\right)\right) + \left(1 - \mathbb{1}_{[n^w>0]}\right)T \\
Y^{L,\iota} &= \frac{n^\iota w^{z,\iota}\left(a^\iota, e^\iota, u^\iota\right)}{1 + \tilde{\tau}_{ss}}, \ \iota = m, w \\
(e^m)' &= e^m + 1, \quad (e^w)' = e^w + \mathbb{1}_{[n^w>0]}, \\
n^m &\in (0,1], \quad n^w \in [0,1], \quad (k^z)' \geq 0, \quad c^z > 0, \\
n^\iota &= 0 \quad \text{if } j \geq 65, \ \iota = m, w.
\end{aligned}
$$

3.7 *Recursive Competitive Equilibrium*

We call an equilibrium of the growth adjusted economy a stationary equilibrium.[15] Let $\Phi^M(k^z, e^w, u^m, u^w, a^m, a^w, x, j)$ be the measure of married households with the corresponding characteristics and $\Phi^S(k^z, e, u, a, \iota, j)$ be the measure of single households. We now define such a stationary recursive competitive equilibrium as follows:

Definition:

1. The value functions $V^M(\Phi^M)$ and $V^S(\Phi^S)$ and policy functions, $c^z(\Phi^M)$, $k^z(\Phi^M)$, $n^m(\Phi^M)$, $n^w(\Phi^M)$, $c(\Phi^S)$, $k(\Phi^S)$, and $n(\Phi^S)$ solve the consumers' optimization problem given the factor prices and initial conditions.

2. Markets clear:

$$K^z + B^z = \int k^z d\Phi^M + \int k^z d\Phi^M$$

$$L^z = \int \left(n^m w^{zm} + n^w w^{zf}\right) d\Phi^M + \int (nw^z)\, d\Phi^S$$

$$\int c^z d\Phi^M + \int c^z d\Phi^S + (\mu+\delta)K^z + G^z = (K^z)^\alpha (L^z)^{1-\alpha}$$

3. The factor prices satisfy:

$$\begin{aligned} w^z &= (1-\alpha)\left(\frac{K^z}{L^z}\right)^\alpha \\ r &= \alpha\left(\frac{K^z}{L^z}\right)^{\alpha-1} - \delta \end{aligned}$$

[15] the associated BGP can of course trivially be constructed by scaling all appropriate variables by the growth factor Z_t.

4. The government budget balances:

$$g^z\left(2\int d\Phi^M + \int d\Phi^S\right) + \int_{j<65,n=0} T^z d\Phi^M + \int_{j<65,n=0} T^z d\Phi^S + G^z + (r-\mu)B^z$$
$$= \int \left(\tau_k r(k^z + \Gamma^z) + \tau_c c^z + \tau_l \left(\frac{n^m w^{mz} + n^w w^{wz}}{1+\tilde{\tau}_{ss}}\right)\right) d\Phi^M$$
$$+ \int \left(\tau_k r(k^z + \Gamma^z) + \tau_c c^z + \tau_l \left(\frac{n w^z}{1+\tilde{\tau}_{ss}}\right)\right) d\Phi^S$$

5. The social security system balances:

$$\Psi^z\left(\int_{j\geq 65} d\Phi^M + \int_{j\geq 65} d\Phi^S\right) = \frac{\tilde{\tau}_{ss} + \tau_{ss}}{1+\tilde{\tau}_{ss}}\left(\int_{j<65} (n^m w^{mz} + n^w w^{wz}) d\Phi^M + \int_{j<65} n w^z d\Phi^S\right)$$

6. The assets of the dead are uniformly distributed among the living:

$$\Gamma^z\left(\int \omega(j) d\Phi^M + \int \omega(j) d\Phi^S\right) = \int (1-\omega(j))\, k^z d\Phi^M + \int (1-\omega(j))\, k^z d\Phi^S$$

4 Calibration

This section describes the calibration of the model parameters. We calibrate our model to match the appropriate moments from the U.S. data. We use data from 2001 - 2007, because our tax data start in 2001 and we want to avoid the business cycle effects during the great recession starting in 2008. Many parameters can be calibrated to direct empirical counterparts without solving the model. They are listed in Table 2. The 10 parameters in Table 3 below are, however, calibrated using an exactly identified simulated method of moments (SMM) approach.

4.1 Preferences

The momentary utility functions are given in equations 7 and 8. The discount factor, β, the means and variances of the fixed costs of working, $\mu_{F^{Mw}}$, $\mu_{F^{Sw}}$, $\sigma^2_{F^{Mw}}$ and $\sigma^2_{F^{Sw}}$, and the disutility parameters of working more hours, χ^{Mm}, χ^{Mw}, χ^{Sm} and χ^{Sw}, are among the parameters found through SMM. The corresponding data moments are the ratio of capital to output, K/Y, taken from the BEA, the employment rates of married and single females (age 20-64), taken from the CPS, the persistence of labor force participation of married and single females (age 20-64)[16], taken from the PSID, and hours worked per person aged 20-64 by marital status and gender, taken from the CPS.

There is considerable debate in the economic literature about the Frisch elasticity of labor supply, see Keane (2011) for a thorough survey. However, there seem to be consensus that female labor supply is much more elastic than male labor supply. We set $1/\eta^m = 0.4$ which is in line with contemporary literature, see for instance Guner, Kaygusuz, and Ventura (2011). $1/\eta^w$ we set to 0.8. Note that $1/\eta^f$ is here to be interpreted as the intensive margin Frisch elasticity of female labor supply, while $1/\eta^m$ is the Frisch elasticity of male labor supply. The $1/\eta$ parameters should generally not be interpreted as the macro elasticity of labor labor supply with respect to tax rates, see Keane and Rogerson (2012).

4.2 Technology

In line with contemporary literature, we set the capital share parameter, α, equal to 1/3. The depreciation rate is set to match an investment-capital ratio of 9.88% in the data.

4.3 Wages

We estimate the age profile for male wages, the experience profile for female wages, and the processes for the idiosyncratic shocks exogenously, using the PSID from 1968-1997. After 1997, it is not possible to get years of actual labor market experience from the PSID. Appendix 9.4 describes the estimation procedure in more detail. We use a 2-step approach to control for selection into the labor market, as described in Heckman (1976) and Heckman (1979). After estimating the returns to age/experience for men/women, we obtain the residuals from the estimations and use the panel data structure of the PSID to estimate the parameters for the productivity shock processes, ρ_ι and σ_ι, and the variance of individual

[16] Measured as the R^2 from regressing this year's participation status on last year's participation status.

abilities, σ_{α_ι}, by fixed effects estimation. We normalize the parameter, γ_{0w} to 1 and calibrate the parameter γ_{0m}, internally in the model. The corresponding data moment is the ratio between male and female earnings.

4.4 Taxes and Social Security

As described in Section 2 we apply the labor income tax function in 1, proposed by Benabou (2002). We use U.S. labor income tax data provided by the OECD to estimate the parameters θ_0 and θ_1 for different family types. Table 4 in the Appendix summarizes our findings for different countries. Table 6 displays the share of labor income taxes paid by different income deciles in our US benchmark economy.

We assume that the social security contributions for the employee, τ_{SS}, and the employer, $\tilde{\tau}_{SS}$ are flat taxes, which is close to true. We use the rate from the bracket covering most incomes, 7.65% for both τ_{SS} and $\tilde{\tau}_{SS}$. We follow Trabandt and Uhlig (2011) and set $\tau_k = 36\%$ and $\tau_c = 5\%$.

4.5 Transition Between Family Types

We assume that there are four family types: (1) single individuals with no children, (2) married couples with no children; (3) married couples with 1 child; (4) married couples with 2 children. To calculate age-dependent probabilities of transitions between married and single, we use the US data from the CPS (March supplement) covering years 1999 to 2001. We assume a stationary environment where the probabilities of transitioning between the family types does not change over time. More precisely, we allow these probabilities to depend on the individual's age, but not on her cohort. Denoting the shares of married and divorced individuals at age j by $\bar{M}(j)$ and $\bar{D}(j)$, we compute the probability of getting married at age j, $M(j)$, and the probability of getting divorced, $D(j)$, from the following

Table 2: Parameters Calibrated Outside of the Model

Parameter	Value	Description	Target
$1/\eta^m, 1/\eta^w$	0.4, 0.8	$U^M(c,n^m,n^w) = \log(c) - \chi^{Mm}\frac{(n^m)^{1+\eta^m}}{1+\eta^m} -$	Literature
		$\chi^{Mw}\frac{(n^w)^{1+\eta^w}}{1+\eta^w} - F^{Mw} \cdot \mathbb{1}_{[n^w>0]}$	
$\gamma_{1m}, \gamma_{2m}, \gamma_{3m}$	$0.109, -1.47 * 10^{-3}, 6.34 * 10^{-6}$	$w_t(a_i, e_i, u_i) = w_t e^{a_i+\gamma_{0m}+\gamma_{1m}e_i+\gamma_{2m}e_i^2+\gamma_{3m}e_i^3+u_i}$	PSID (1968-1997)
$\gamma_{1w}, \gamma_{2w}, \gamma_{3w}$	$0.078, -2.56 * 10^{-3}, 2.56 * 10^{-5}$	$w_t(a_i, e_i, u_i) = w_t e^{a_i+\gamma_{0w}+\gamma_{1w}e_i+\gamma_{2w}e_i^2+\gamma_{3w}e_i^3+u_i}$	
$\sigma_m, \sigma_w,$	0.319, 0.310	$u' = \rho_{jg}u + \epsilon$	
ρ_m, ρ_w	0.396, 0.339	$\epsilon \sim N(0, \sigma_{jg}^2)$	
σ_{am}, σ_{aw}	0.338, 0.385	$a_\iota \sim N(0, \sigma_{a_m}^2)$	
$\theta_0^S, \theta_1^S, \theta_0^{M0}, \theta_1^{M0}$	0.8177, 0.1106, 0.8740, 0.1080	$ya = \theta_0 y^{1-\theta_1}$	OECD tax data
$\theta_0^{M1}, \theta_1^{M1}, \theta_0^{M2}, \theta_1^{M2}$	0.9408, 0.1585, 1.0062, 0.2036	$ya = \theta_0 y^{1-\theta_1}$	
τ_k	0.36	Capital tax	Trabandt and Uhlig (2011)
$\tau_{ss}, \tilde{\tau}_{ss}$	(0.0765, 0.0765)	Social Security tax	OECD
τ_c	0.05	Consumption tax	Trabandt and Uhlig (2011)
T	$0.2018 \cdot AW$	Income if not working	CEX 2001-2007
G/Y	0.0725	Pure public consumption goods	2X military spending (World Bank)
B/Y	0.6185	National debt	Government debt (World Bank)
$\omega(j)$	Varies	Survival probabilities	NCHS
$M(j)$, $D(j)$	Varies	Marriage and divorce probabilities	CPS
$\Xi(x,j)$	Varies	Distribution of children	NLSY
$\Upsilon(x,x',j)$	Varies	Transition probabilities # of children	NLSY
k_0	$0.4409 \cdot AW$	Savings at age 20	NLSY97
μ	0.0200	Output growth rate	Trabandt and Uhlig (2011)
δ	0.0788	Depreciation rate	$I/K - \mu$ (BEA)

transition equations:

$$\bar{M}(j+1) = (1-\bar{M}(j))M(j) + \bar{M}(j)(1-D(j)),$$
$$\bar{D}(j+1) = \bar{D}(j)(1-M(j)) + \bar{M}(j)D(j).$$

As mentioned above, we assume that only married couples have children. To compute the probabilities of transitioning between 0, 1 and 2 children, we use the NLS data that follows individuals over the period from 1979 to 2010. Since it is a panel data set, we can compute the age-dependent probabilities of switching between 0, 1 and 2 children as households age over this period. Newly wed households draw their number of children from the unconditional age-dependent distribution.

4.6 Death Probabilities and Transfers

We obtain the probability that a retiree will survive to the next period from the National Center for Health Statistics.

People who do not work have other source of income such as unemployment benefits, social aid, gifts from relatives and charities, black market work etc. They do also have more time for home production (not included in the model). Pinning down the consumption equivalent of income when not working is a difficult task. The number we land on will also clearly affect the size of the fixed costs of working, which we calibrate to hit the employment rate for women by marital status. As an approximation for income when not working, we take the average value of non-housing consumption of households with income less than \$5000 per year from the Consumer Expenditure Survey. When we perform policy experiments we keep income when not working as a constant fraction of the income of those who work.

To determine the spending on pure public consumption G we follow Prescott (2004) and assume that government expenditure on pure public consumption goods is equal to 2 times expenditure on national defense. In addition the government must pay interest on the national debt before the remaining tax revenues can be redistributed lump sum to

Table 3: Parameters Calibrated Endogenously

Parameter	Value	Description	Moment	Moment Value
γ_{0m}	-1.188	$w_t(a_i, e_i, u_i) = w_t e^{a_i+\gamma_{0w}+\gamma_{1w}e_i+\gamma_{2w}e_i^2+\gamma_{3w}e_i^3+u_i}$	Gender earnings ratio	1.569
β	1.008	Discount factor	K/Y	2.640
$\mu_{F^{Mw}}$	-0.056	$F^{Mw} \sim N(\mu_{F^{Mw}}, \sigma^2_{F^{Mw}})$	Married fem employment	0.676
$\sigma_{F^{Mw}}$	0.197	$U^M(c, n^m, n^w) = \log(c) - \chi^{Mm}\frac{(n^m)^{1+\eta^m}}{1+\eta^m} -$	R^2 from $\mathbb{1}_{[n_t>0]} = \rho_0 + \rho_1 \mathbb{1}_{[n_{t-1}>0]}$	0.553
χ^{Mw}	4.140	$\chi^{Mw}\frac{(n^w)^{1+\eta^w}}{1+\eta^w} - F^{Mw} \cdot \mathbb{1}_{[n^w>0]}$	Married female hours	0.224 (1225 h/year)
χ^{Mm}	20.500		Married male hours	0.360 (1965 h/year)
$\mu_{F^{Sw}}$	-0.029	$F^{Sw} \sim N(\mu_{F^{Sw}}, \sigma^2_{S^{Mw}})$	Single fem. employment	0.760
$\sigma_{F^{Sw}}$	0.227	$U^S(c, n, \iota) = \log(c) - \chi^{S\iota}\frac{(n)^{1+\eta^\iota}}{1+\eta^\iota}$	R^2 from $\mathbb{1}_{[n_t>0]} = \rho_0 + \rho_1 \mathbb{1}_{[n_{t-1}>0]}$	0.463
χ^{Sw}	8.700	$-F^{S\iota} \cdot \mathbb{1}_{[n>0]}$	Single female hours	0.251 (1371 h/year)
χ^{Sm}	66.000		Single male hours	0.282 (1533 h/year)

households.

4.7 Estimation Method

Ten model parameters are calibrated using an exactly identified simulated method of moments approach. We minimize the squared percentage deviation of simulated model statistics from the ten data moments in column 3 of Table 3. Let $\Theta = \{\gamma_{0m}, \beta, \mu_{F^{Mw}}, \sigma_{F^{Mw}}, \chi^{Mw}, \chi^{Mm}, \mu_{F^{Sw}}, \sigma_{F^{Sw}}, \chi^{Sw}, \chi^{Sm}\}$ and let $V(\Theta) = (V_1(\Theta), \ldots, V_{10}(\Theta))'$ denote the vector where $V_i(\Theta) = (\bar{m}_i - \hat{m}_i(\Theta))/\bar{m}_i$ is the percentage difference between empirical moments and simulated moments. Then:

$$\hat{V} = \min_{\Theta} V(\Theta)'V(\Theta) \tag{9}$$

Table 3 summarizes the estimated parameter values and the data moments. We match all the moments exactly so that $V(\Theta)'V(\Theta) = 0$.

5 Computational Experiments

This section concisely describes our counterfactual experiments in Sections 6 and 7. We start by calibrating the model to data from the U.S. (and in Section 7 Germany). We then perform the following exercises, in order to make the points that a) the progressivity of the tax code is a key determinant of the shape of the Laffer curve, and that b) the precise form of household heterogeneity present in the model is crucial for the quantitative magnitude of the impact of tax progressivity on the Laffer curve. The latter point is important since coutries differ significantly along this dimension and therefore the extent to which progressivity is crucial for tax revenues (and thus the Laffer curve) will vary across countries as well.

The quantitative analysis therefore proceeds in the following steps:

1. For a given model and given progressivity of the tax code defined by the parameter θ_1 we derive the Laffer curve by scaling up the tax level (which can be adjusted by θ_0) for all family types by the same constant and plotting BGP tax revenue against the level of taxes. We study the importance of the progressivity of the income tax code for the Laffer curve by tracing out Laffer curves for different degrees of progressivity θ_1. In section 6.1 we trace out U.S. Laffer curves under the assumption that additional tax revenue is transfered back to households in a lump-sum fashion (we call them g-Laffer curves). Section 6.2 does the same, but under the assumption that the additional tax revenue is used to service a larger stock of outstanding government debt (we call them b-Laffer curves), thereby also characterizing the maximal sustainable stock of government debt.

   One should note that while in the representative agent setting, g- and b-Laffer curves coincide (see Feve, Matheron, and Sahuc (2013)), in a model with heterogeneous agents and incomplete asset markets, they are different. Going from g-Laffer curves to b-Laffer curves, one can expect two effects on the tax revenues: i) Smaller lump-sum transfers from the government back to the households mean smaller negative income effect on the labor supply (this can lead to larger effects on tax revenues from the changes in the tax level and / or tax progressivity). ii) An increase in public debt crowds out physical capital, raising the equilibrium interest rate and lowering the equilibrium wages, thereby reducing the tax base (this can lead to smaller effects on tax revenues from the change in the tax level in or tax progressivity).

2. We then investigate the importance of the form and size of household heterogeneity for the impact of tax progressivity on tax revenues. In a first step, carried out in

section 6.3, we show, for a fixed degree of tax progressivity θ_1, what forms of household heterogeneities impact Laffer curves the most, in a quantitative sense. To do so we display Laffer curves for a sequence of models, starting with Trabandt and Uhlig's (2011) representative agent model and ending with our benchmark life cycle economy with ex-ante and ex-post heterogeneity as well as explicit family structure and extensive margin labor supply margin of females. In a second step, in section 6.4 we then study the interaction between tax progressivity and household heterogeneity by displaying how maximal tax revenue and debt levels depend on the progressivity of the tax code in a selection of models that differ in the way and the degree to which households are heterogeneous.

3. Finally, we draw out the implications of these findings for Laffer curves across countries. Cross-country differences in the tax code (especially its progressivity, but also its structure - labor, capital and consumption taxes) and the magnitude of household heterogeneity are the key drivers of cross-country differences in Laffer curves. We demonstrate this claim in section 7 by comparing Laffer curves for the U.S. and Germany, decomposing the importance of both factors by first subjecting our model calibrated to the U.S. data to a tax code with German progressivity level, and then by re-calibrating the model fully to German micro data and drawing Laffer curves for a tax code with U.S. progressivity level.

6 The Impact of Tax Progressivity and Household Heterogeneity on the Laffer Curve

In this section we display the main quantitative results of our paper, with respect to the impact of tax progressivity and household heterogeneity on the Laffer curve. We trace out the Laffer curve under two different assumptions about the use of revenues. In the first specification (g-curves), we assume that the increase in revenue is redistributed evenly to all households. In the second specification (b-curves), we assume that the increase in revenue is spent on paying interest on debt.

We find that more progressive taxes significantly shift the Laffer curve downwards and reduce the maximum sustainable debt level. We also find that various types of heterogeneity is important for the maximal revenue that can be raised and the location of the peak of the Laffer curve.

6.1 The Impact of Tax Progressivity

In this subsection we characterize U.S. Laffer curves under the assumption that the increase in revenue is redistributed uniformly to all households. This is similar to Trabandt and Uhlig (2011), and we denote these Laffer curves g-curves. We vary the progressivity of the labor income tax schedule, as defined by 2, by multiplying θ_1 for all family types by the same constant and we change the tax level while holding progressivity constant by multiplying θ_0 for all family types by the same constant.

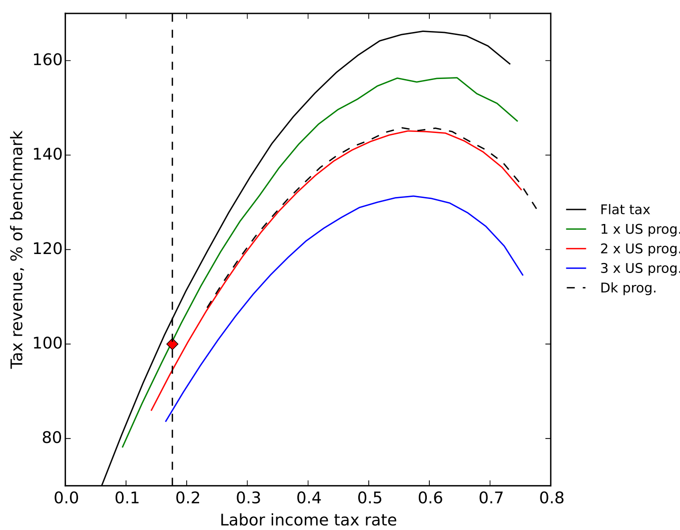

Figure 2: The Impact of Tax Progressivity the Laffer Curve (holding debt to GDP constant)

In Figure 2, we plot Laffer curves for our simulated US economy for varying degrees of progressivity. At the moment the US is relatively far from the peak of its Laffer curve. With the current progressivity of the tax system, tax revenues can be increased by about 56% if the average tax rate on labor income is raised from 17% today to about 58%. Figure 11 in the Appendix provides a break down of the revenue from labor, consumption and capital taxes along the Laffer curve.

We observe that the design of the tax system has considerable impact on the Laffer curve. The maximal revenue that can be raised with a flat tax system is about 6% higher than the maximal revenue that can be raised when the tax schedule exhibits a progressivity similar to the current US system. A tax schedule with the current US progressivity can again raise 7% more revenue than a tax system which is twice as progressive, or similar to the tax system in Denmark[17].

Figure 2 also allows us to assess how important is tax progressivity relative to the tax level in achieving the maximum labor income tax revenues. Let TR_{cur} be the tax revenues that correspond to the current labor income tax level in the US (marked by a red dot in the figure), TR_{level} be the maximum tax revenues that can be attained by changing the tax level but keeping the progressivity as it is now in the US (which corresponds to the top of the "1 x US prog." curve), and finally let TR_{prog} be the maximum tax revenues one can achieve with flat taxes (which corresponds to the top of the "Flat tax" curve in the figure). Then the total maximum change in tax revenues is $\Delta\text{Total} = TR_{\text{prog}} - TR_{\text{cur}} = (1.56 \cdot 1.06 - 1)TR_{\text{cur}}$, while the change that is due to modifying the tax progressivity is $\Delta Prog = TR_{\text{prog}} - TR_{\text{level}} = TR_{\text{prog}} - TR_{\text{level}} = (1.56 \cdot 1.06 - 1.56)TR_{\text{cur}}$. This means that the potential changes due to modifying the progressivity of the tax code, ΔProg, can account for up to 14.3% of all additional tax revenues one could achieve when changing the current US labor tax system to the one that results in the highest tax revenues, changing both the tax level and tax progressivity.[18]

Table 7 displays different model statistics for 3 different levels of progressivity at 17.5%[19],

[17]Note that the Danish tax system is generally more progressive than the US tax system, however, as we scale the progressivity of the US system we will never obtain a system exactly equal to the Danish system since the U.S. and Danish systems also differ in the relative tax burdens of different family types.

[18]Imposing the restriction that the tax system remains in the class of tax functions that we consider in this paper.

[19]The benchmark tax level

25% and 35% average labor income tax rate. As one can can see from the table, for a given tax level, a more progressive tax schedule leads to lower aggregate labor supply and savings. This is the reason for why a more progressive tax system gives smaller revenues. It is interesting to note that the progressivity of the tax system has a strong impact on female labor force participation and that this impact is completely opposite for married and single women. Women are often low earners and for single women a more progressive tax system increases the benefits from work. Married women are on the other hand taxed jointly with their husbands. If the husband is a high earner, the additional benefits from the wife participating in the labor force will be smaller with a more progressive tax system.

Table 8 displays different model statistics for 3 different progressivity levels while holding θ_0 in the tax function constant at the levels which give 17.5%, 25% and 35% average tax with US tax progressivity. As can be seen from the table, starting at a given average tax level there is some but limited potential for raising more revenues by making the tax system more progressive. Starting from a 35% average labor income tax rate and the same tax progressivity as in the US and then making the tax system twice as progressive does for instance reduce tax revenues even if the average tax rate increases to 38%.

In Figure 2 one may notice that the there are some non-monotone areas on the Laffer curves. This happens because of the extensive margin for women. Relatively large chunks of women leave the labor force around the same tax rate and this causes a drop in revenue[20]. With more heterogeneity in the fixed costs (but also higher computational cost) it is possible to get smoother Laffer curves. In Figure 9 we plot the Laffer curve for US progressivity (the green line in Figure 2), using 15 different discrete costs of labor force participation instead of 3. This Laffer curve is almost smooth.

6.2 The Impact of Tax Progressivity on Sustainable Debt

In the left panel of Figure 3, we plot Laffer curves for our simulated US economy under the assumption that the increase in revenue (again brought about by an increase in θ_0) is spent

[20]Figure 10 in the Appendix plots female LFP along the Laffer curve.

on paying interest on debt. We call these b-Laffer curves. Government spending, G, and lump sum transfers, g are kept at their benchmark levels in this exercise.

The peak of the Laffer curve is higher when we instead of redistributing revenues spend them on paying off debt. The positive income effect on labor supply is dominating the effect of debt crowding out productive capital. For the current choice of progressivity, the US can increase it's revenue by about 95% if the average labor income tax rate is increased to about 55%. Also for the b-laffer curves, a more progressive tax system significantly reduces revenue. The maximal revenue that can be raised with a flat tax system is about 7% higher than the maximal revenue that can be raised when the tax schedule exhibits a progressivity similar to the current US system. A tax schedule with the current US progressivity can again raise 10% more revenue than a tax system which is twice as progressive

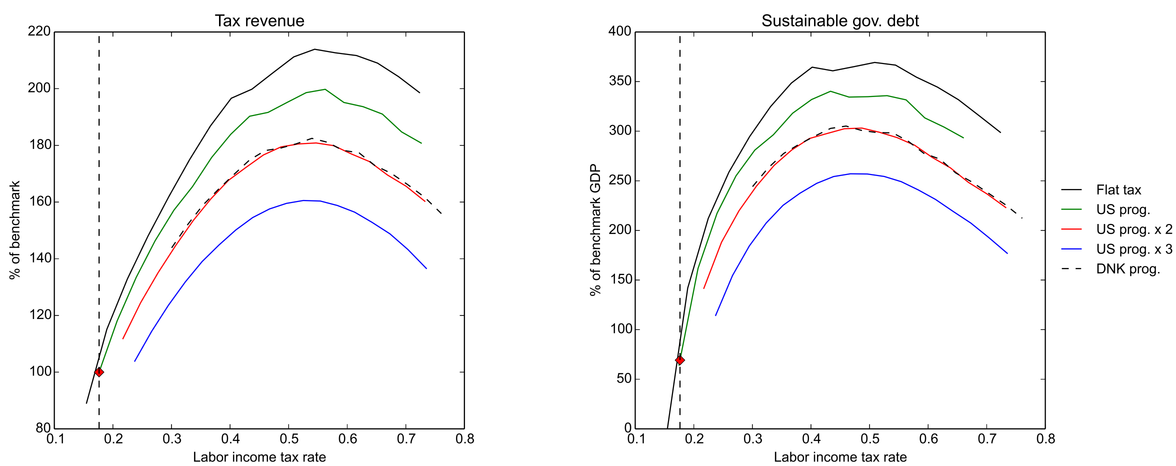

Figure 3: Tax Revenue and Maximum Sustainable Debt Level by Tax- Level and Progressivity

In the right panel of Figure 3 we plot the maximum sustainable debt level as a function of the average tax rate for varying degrees of progressivity. For it's current choice of progressivity, the US can sustain a debt burden of about 3.3 times it's benchmark GDP by increasing the average tax rate to 42%. This is consistent with the fact that the interest rate on US debt in international bond markets is still relatively low, although in recent years (after the calibration period) the US debt has risen to 120% of GDP. We observe that one also can sustain more debt with a less progressive tax system. Converting to a flat tax system increases the maximum sustainable debt by 8% whereas converting to a twice as progressive tax system reduces the maximum sustainable debt by 11%. The tax rate, which maximizes debt is substantially lower than the tax rate which maximizes revenue. This is due to general equilibrium effects. As the debt level increases, the capital stock becomes smaller, the interest rate increases and it becomes more expensive to hold debt.

6.3 The Impact of Household Heterogeneity

In this section we analyze how the shape of the Laffer curve depends on different types of household heterogeneity. To do this, we consider several alternative models. We start with our model from section 3, and then remove some of its key features, such as participation margin, returns to experience, life-cycle profiles, and agent heterogeneity in permanent abilities and idiosyncratic productivity shocks, finally arriving at the representative agent model analyzed by Trabandt and Uhlig (2011).

To facilitate comparison between models with infinitely lived agents and models with a life-cycle, in this section we consider Laffer curves for which the tax revenue includes the revenue from the social security taxes and we focus on g-curves[21]. This allows us to compare our findings to Trabandt and Uhlig (2011) who use the same approach. We also assume that taxes are flat (no progressivity) in all models in this section.

In the left Panel of Figure 4 we graph 6 g-Laffer curves. The green line is the Laffer curve from our original model. The green dashed line is from the full model without the extensive margin and human capital accumulation for women. The green dotted line is from the full model with extensive margin, however, instead of endogenous experience accumulation there is an exogenous age-dependent wage profile. The blue dashed line and the blue solid line are from the representative agent model of Trabandt and Uhlig (2011). In the solid line

[21] In the previous sections we kept social security taxes separate, because in reality they are a separate system. They are not part of the government budget and cannot be spent on paying down government debt.

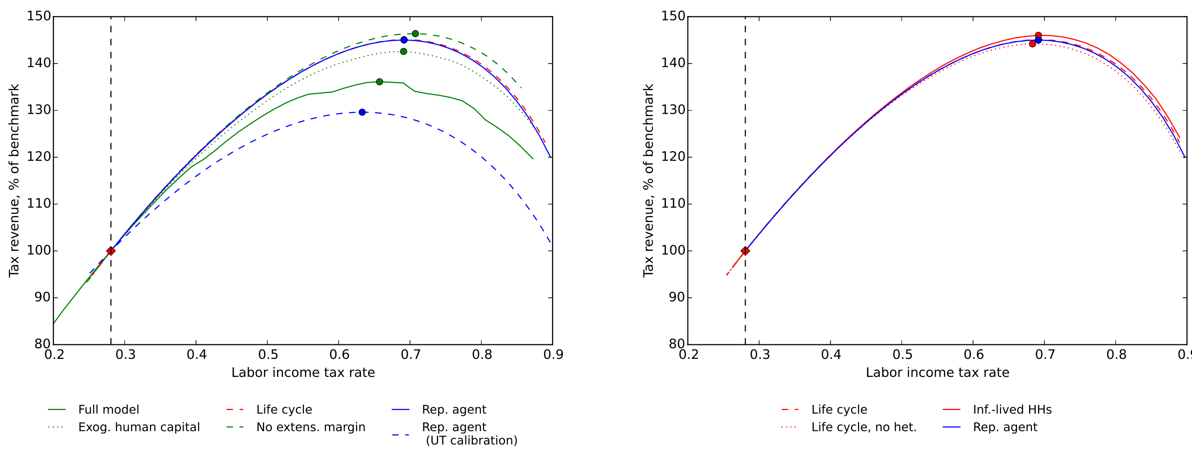

Figure 4: Laffer Curves for Different Models With Flat Taxes

we use their code but parameter values similar to those used in our study. In particular we set the parameter η which governs the Frisch elasticity of labor supply equal to 1/0.6, the average of what we use for men and women in the full model. The dotted blue line is from Trabandt and Uhlig (2011)'s original calibration with $\eta = 1$. The red dashed line is the Laffer curve from a single-household life-cycle model with heterogeneity in permanent abilities and idiosyncratic productivity shocks.

Among the Laffer curves with $\eta = 1/0.6$, the one for the full model stands out as by far the lowest. This is as expected because it has both extensive margin labor supply and human capital for females. Between these two model elements the human capital effect is, however, the main driver of the level of the Laffer curve. Higher taxes reduce female labor force participation, which again lowers their productivity due to the loss of human capital. Introducing an extensive margin in female labor supply while keeping the age-profile of female wages constant also lowers the Laffer curve due to more elastic labor supply, however, the effect is much larger when female wages depend on experience.

Whether one uses an infinite horizon model or a single household life-cycle model with or without heterogeneity in shocks and permanent abilities has very little effect on the Laffer curve, see the right panel of Figure 4. This is in line with Trabandt and Uhlig (2011), who found that augmenting their representative agent with household heterogeneity did not have much of an effect on the Laffer curve.

As one would expect, the η parameter, which in the representative agent model is equal to the inverse of the Frisch elasticity of labor supply, has a large impact on the Laffer curve, see the left panel of Figure 13 in the Appendix. In the representative agent model with $\eta = 1/0.4$, which would be considered relatively conservative, the US can increase it's revenue to almost 160% of benchmark by increasing the average tax rate to about 78%. With $\eta = 1/1.5$, the Laffer curve peaks at 58% and the maximum revenue is only 120% of benchmark. In the left panel of Figure 4 the difference between the the blue dotted line and blue solid line is due to increasing this parameter from 1 to 1/0.6. The fact that our heterogeneous agent model, which is calibrated with $\eta_m = 1/0.4$ and $\eta_f = 1/0.8$ produce a Laffer curve close to the same level as the representative agent model with $\eta = 1$, illustrates that "macro" and "micro" elasticities of labor supply are two different concepts[22], although the main explanation is the human capital effect.

In Figure 14 in the Appendix we plot b-Laffer curves and maximal sustainable debt levels from different models. We only display results for life-cycle models, which has a social security system. The results are relatively similar to the ones for g-curves. The full model with endogenous human capital and extensive margin labor supply for females generates less revenue and can sustain less debt compared to benchmark GDP. Income heterogeneity matters slightly more for the maximum sustainable debt level than for revenue, although the effect is small. The sustainable debt level is lower in the single household life-cycle model with heterogeneity in permanent abilities and idiosyncratic shocks than in the life-cycle model without other heterogeneity than age.

[22] Micro estimates of the Hicksian or Marshallian elasticity of labor supply have usually been based on the change in individual intensive margin labor supply from one year to the next. The "macro" elasticity between two steady states also takes into account the change in the population's labor force participation due to a tax change.

6.4 *The Interaction Between Heterogeneity and Progressivity*

In the left panel of Figure 5 we plot the peak of the Laffer g-curves as a function of tax progressivity in different models; our benchmark heterogeneous agents model, a model which is identical to the benchmark model except that female human capital is age-dependent and exogenous, a model which is identical to the exogenous human capital model except that it lacks extensive margin labor supply for females, a representative agent model, and a single household life-cycle model.

The negative impact of progressivity on tax revenue is the smallest in our full model and the largest in the single household life-cycle and representative agent models. Adding family-type heterogeneity (No extensive margin) reduces the impact of progressivity. This is driven by progressive taxation being less distortionary on the intensive margin of labor supply for 2-earner households, when they are taxed jointly[23], which is the case in the US. To see this, compare the first order condition for a married individual (in this case the female) to the first order condition for a single individual. For a married female, the first order condition with respect to labor would read:

$$u_c' w_f (1 - \underbrace{(\tau + \theta_0 \theta_1 (\frac{w_m n_m + w_f n_f}{AE})^{-\theta_1})}_{\text{tax wedge}}) = -u_n' \tag{10}$$

The first order condition for a single female would read:

$$u_c' w_f (1 - \underbrace{(\tau + \theta_0 \theta_1 (\frac{w_f n_f}{AE})^{-\theta_1})}_{\text{tax wedge}}) = -u_n' \tag{11}$$

Thus the distortionary tax wedge is smaller for married couples under joint taxation. Adding an extensive margin of female labor supply (Exog. human capital) increases the impact of progressivity, as some women are pushed over the margin. However, introducing endogenous human capital accumulation again (Full model) significantly reduces the impact

[23] This may be an argument for joint taxation of married couples if the tax system is highly progressive. However, it should be noted that the effect on the extensive margin tends to go in the opposite direction.

of tax progressivity. This is because labor supply becomes much more inelastic around the extensive margin. From figure 10 one can see that female LFP tend to be slightly higher when taxes are more progressive in the full model.

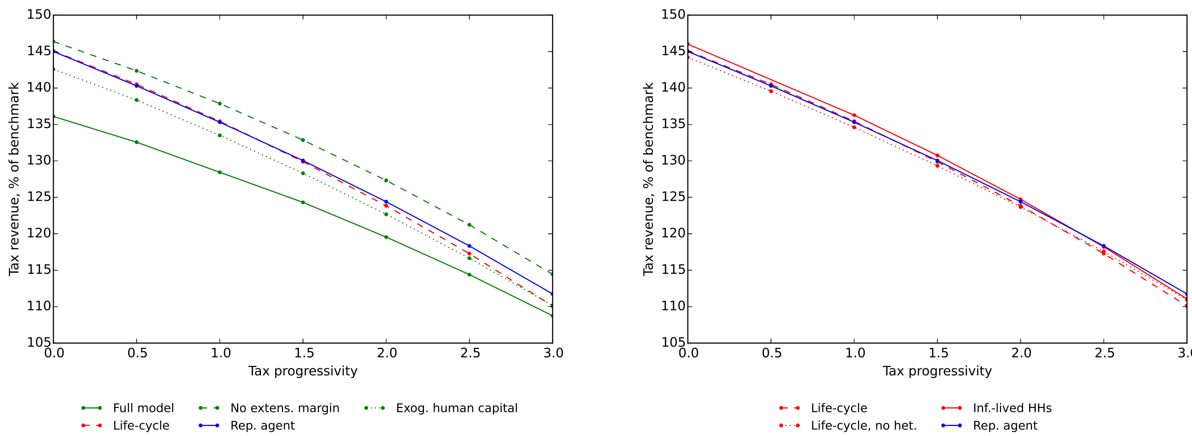

Figure 5: The Impact of Tax Progressivity on Maximum Revenue in Different Models

It should be noted here that the finding that introducing endogenous human capital accumulation reduces the impact of tax progressivity may depend crucially on how human capital accumulation is modeled. When human capital is modeled as years of labor market experience, making taxes more progressive increases the short term benefit of acquiring human capital. This effect counteracts the effect from progressive taxes reducing the longer time returns to human capital. Progressive taxation in this context only affects the human capital accumulation decisions of those on the margin between working and not working. These are usually low earners and will get a higher net wage (at least in the short run) when taxes become more progressive. If human capital was rather modeled as an investment of money in education quality or as a time-investment in learning, the introduction of human capital may instead increase the importance of tax progressivity[24].

We conjecture that one may approximate the level of the Laffer curve relatively well with

[24] See Holter (2014) for a model where human capital accumulation is modeled as a continuous investment of money in education quality and Badel and Huggett (2014) for a model where human capital accumulation is modeled as investment of time in learning. Both of these studies apply a Ben-Porath (1967) human capital production technology.

a representative agent model, which has the "right" elasticity of labor supply. By "right" in this context we mean that labor supply must be made sufficiently elastic to make up for the human capital effect which is not present in the representative agent model[25]. However, as figure 5 shows, the effect of changing the progressivity of the tax system would not be captured very well by a representative agent model, no matter the elasticity of labor supply. Since tax progressivity differs among countries, the representative agent model with a fixed η would also not be well-suited for cross-country comparisons of Laffer curves.

The right panel of Figure 13 in the Appendix illustrates how the impact of progressivity changes when changing the elasticity of labor supply in a representative agent model. We observe that the negative impact of progressivity on revenue is greater when the elasticity of labor supply is higher. However, even for low labor supply elasticity going from a flat tax to a tax system which is 3 times more progressive than the current US system, lowers the peak of the Laffer curve by an amount equal to 30% of benchmark revenue. The impact of changing the elasticity of labor supply on the cost of tax progressivity is relatively small compared to the impact of introducing model elements such as 2-earner households, extensive margin labor supply and human capital.

There is very little interaction between the impact of tax progressivity on revenue and income inequality modeled as variation in permanent abilities or idiosyncratic shocks, see the right panel of figure 5. This may imply that societies with higher ex-ante inequality should choose a more progressive tax system because the gains from redistribution would be higher in such a society. This conclusion would as we have seen also hold up if higher inequality was due to greater returns to experience but perhaps not if inequality was due to higher returns to education.

In Figures 16 and 17 in the Appendix we conduct a sensitivity analysis with respect to the interaction between income heterogeneity and progressivity. We plot maximum revenue,

[25]In figure 12 we plot Laffer curves for the benchmark model and a representative agent model wit η set to generate the same implied labor supply elasticity after a productivity shock. As can be seen from the figure the resulting Laffer curve in the representative agent model is far higher than in the full model.

the revenue maximizing tax rate, labor supply in hours at the revenue maximizing point and labor supply in efficiency units of labor at the revenue maximizing point in a single household life-cycle model with and without heterogeneity in abilities and idiosyncratic shocks. We perform the exercise using log utility with very low, medium and very high elasticity of labor supply, constant relative risk aversion utility with $\sigma = 4$ and $\eta = 1/0.6$, Cobb-Douglas utility, and Greenwood-Hercowitz-Huffman utility.[26] With all these specifications, income heterogeneity has very little impact on the Laffer curve.

Figure 15 in the Appendix displays the impact of tax progressivity on maximum revenue and maximum sustainable debt in different models[27]. The results are qualitatively similar to the results for g-curves. The impact of progressivity is the largest in the single-household life-cycle model. Progressivity matters less when we model family-type heterogeneity, more when we introduce extensive margin labor supply and less when we introduce endogenous human capital. Heterogeneity plays some but limited impact for the level of debt that can be sustained. With more heterogeneity, agents on average increase savings relatively less as the interest rate increases along the Laffer curve. The result is that the interest rate increases relatively faster in the economy with more heterogeneity and less debt can be sustained.

7 International Laffer Curves

In this section we derive the implications of our previous findings for the international comparison of tax revenues and maximally sustainable debt levels. Cross-country differences in the tax code (labor income tax progressivity, but also capital and consumption taxes) and the magnitude of household heterogeneity and thus inequality are the key drivers of cross-country differences in Laffer curves. In this section we demonstrate this by example; specifically, we compare the Laffer curves for the U.S. and Germany. We choose Germany for two reasons: first, it offers micro wage data (through the German Socio-Economic Panel,

[26] Since all utility specifications do not admit a balanced growth path we abstract from technological progress in this analysis.

[27] Again we only display results for life-cycle models.

GSOEP) that are directly comparable to the American PSID, and second, the differences in the structure of the tax and transfer system between the U.S. and Germany are very substantial, making this cross-country comparison an ideal test case for our theory.

7.1 What if the U.S. Switches to German Labor Income Taxes?

In a first step we now introduce a tax system with German progressivity in our U.S. calibrated economy. In Figure 6, we draw Laffer curves (with extra revenues transferred back to households, i.e. g-curves) for U.S. labor income tax progressivity (the benchmark model) and German labor income tax progressivity. The dots on the curves marks the current tax level in the two countries. As expected, the Laffer curve for the more progressive tax system with progressivity similar to Germany lays below our Laffer curve with U.S. progressivity level. With U.S tax progressivity one can increase tax revenues to 156% of the benchmark value in the U.S., whereas with German tax progressivity (applied to the U.S. economy) one can only raise 150% of benchmark revenue.

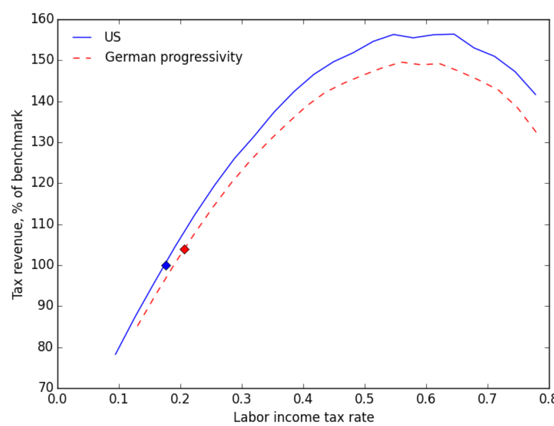

Figure 6: Laffer Curves With German Taxes

To investigate the impact of the wage distribution, in a second step we substitute the exogenously estimated U.S. wage process from the PSID with its German equivalent from the GSOEP and we replace the U.S. calibration target for the ratio between male and female wages with its German equivalent, see Tables 9 and 10. The tax system and all the other data moments are left unchanged during the calibration. In Figure 7 we plot Laffer curves for this economy with U.S. tax progressivity and German tax progressivity. The difference between the two Laffer curves is similar to the benchmark economy. Both Laffer curves are, however, shifted down by about five percentage points. With U.S. tax progressivity and German wages one can raise 152% of benchmark revenue, whereas with German tax progressivity one can only raise 145% of benchmark revenue. One reason for why the Laffer curve shifts down with a German wage structure is the larger gender wage gap in Germany, which causes women to drop out faster from the labor force as one increases the level of taxes.

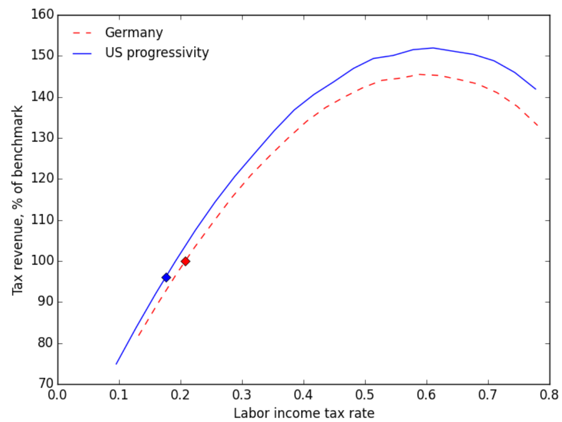

Figure 7: g-Laffer Curves from a Calibration with German Wage Distribution

7.2 What if Germany Switches to U.S. Labor Income Taxes?

Now we re-calibrate the entire model to German data. Relative to U.S. fiscal policy, the German tax system is characterized by different family specific labor income taxes (see Table 4), a 23% capital tax, compared to 36% for the U.S., and a 15% consumption tax, compared to 5% for the U.S. The employee and employer social security taxes, τ_{ss}, and $\tilde{\tau}_{ss}$ are approximated as flat taxes, with a rate that is equal to the contribution by a person with average income. The German social security rates are $\tau_{ss} = 17.1\%$, and $\tilde{\tau}_{ss} = 17.6\%$, compared to $\tau_{ss} = \tilde{\tau}_{ss} = 7.7\%$ for the U.S. Germany also has different marriage and divorce rates, fertility rates and different labor market calibration targets. Tables 10 and 9 in the Appendix summarize the German calibration.

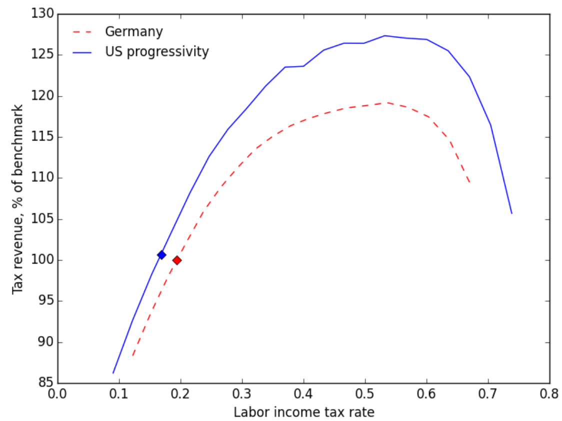

Figure 8: g-Laffer Curves from a Model Calibrated to Germany

In Figure 8 we plot Laffer curves for our German economy with German labor income tax progressivity and with U.S. progressivity. As can be seen from the figure, Germany has a much smaller potential for raising revenue through increased labor income taxation than the U.S. The main reason is that Germany already has much higher consumption- and social security taxes and therefore cannot raise that much more additional revenue through increasing the labor income tax level. Changing to a less progressive tax system increases revenue even more in Germany than in the U.S., however. With U.S. tax progressivity, Germany can maximally raise 127% of their current revenue through increasing labor income taxes. With German progressivity level, the corresponding number is 119%. Thus, an important lesson from the cross-country analysis is that countries (such as Germany) with higher social security and consumption taxes face substantially tighter limits to their ability for generating extra revenue from labor income tax reform.

8 Conclusion

In this paper we quantified how much revenue the U.S. can raise and how much debt it can sustain through increasing labor income taxes, and we studied the impact of tax progressivity and household heterogeneity on the Laffer curve. The U.S. is currently far from the peak of it's Laffer curve and could increase revenue by about 56% if the average labor income tax rate is increased to about 58%.

More progressive taxation significantly reduces tax revenue. Because, as we document, there is substantial variation in tax progressivity across countries, tax progressivity is important for international comparisons of Laffer curves. To quantify the effect of tax progressivity on the Laffer curve it is important to model family-heterogeneity, extensive margin labor supply and endogenous human capital accumulation. These model elements also significantly affect the level of the Laffer curve. Relative to simple life-cycle or representative agent models, with joint taxation, the labor supply of couples is less elastic to changes in tax progressivity along the intensive margin. Adding an extensive margin and endogenous accumulation of labor market experience also reduces the elasticity of labor supply to tax progressivity.

Income heterogeneity, modeled as permanent abilities or idiosyncratic wage shocks, have very little impact on the Laffer curve in simple life-cycle and representative agent models[28]. From a welfare perspective this may imply that countries with more ex-ante heterogeneity should choose a more progressive tax system,as the re-distributive benefits will be larger and the cost approximately equal.

9 Appendix

9.1 Balanced growth with labor participation margin

As is well-known[29], for balanced growth we need to assume labor-augmenting technological progress. In this case, consumption, investment, output and capital all grow at the rate of labor-augmenting technical progress, while hours worked remain constant. King, Plosser, and Rebelo (2002) show that the momentary preferences that deliver first-order optimality

[28]In the full model there would be more complex interactions between these model elements and for instance the extensive margin of labor supply.

[29]See King, Plosser, and Rebelo (2002) for details

conditions consistent with these requirements can take one of the following two forms:

$$U(c,n) = \frac{1}{1-\nu} c^{1-\nu} v(n) \quad \text{if } 0 < \nu < 1 \text{ or } \nu > 1,$$
$$U(c,n) = \log(c) + v(n) \quad \text{if } \nu = 1.$$

To reformulate the household problem recursively, one replaces consumption with its growth-adjusted version in both the household's budget constraint and the household's objective function (see the next subsection for the details). With the second version of the momentary utility function, such "adjustment terms" drop out into a separate additive term which can be ignored:

$$E_t \sum_{j=J}^{100-J} \beta^j \left[\log(c_{t,j}) + v(n_j) - F\mathbb{1}_{[n_j>0]}\right] = E_t \sum_{j=J}^{100-J} \beta^j \left[\log(c_{t,j}/Z_t) + v(n_j) - F\mathbb{1}_{[n_j>0]} + \log(Z_t)\right]$$
$$= E_t \sum_{j=J}^{100-J} \beta^j \left[\log(c_j^z) + v(n_j) - F\mathbb{1}_{[n_j>0]}\right] + E_t \sum_{t=j} \beta^t \log(Z_t)$$

where $c_j^z = c_{t,j}/Z_t$.

This procedure would not work with the first version of the momentary utility function. Proceeding the same way, we would obtain:

$$E_t \sum_{j=J}^{100-J} \beta^j \left[\frac{1}{1-\nu} c_{t,j}^{1-\nu} v(n_j) - F\mathbb{1}_{[n_j>0]}\right] =$$
$$E_t \sum_{j=J}^{100-J} \tilde{\beta}^j \left[\frac{1}{1-\nu} (c_j^z)^{1-\nu} v(n_j)\right] - E_t \sum_{j=J}^{100-J} \beta^j F\mathbb{1}_{[n_j>0]}$$

where $\tilde{\beta} = \beta Z^{1-\nu}$. This means that as time passes by, fixed participation costs become "more important" for the houshold (since it uses the original discount factor, β).

9.2 Recursive formulation of the household problem

Households of age J in period t maximize

$$U = E_t \sum_{j=J}^{100-J} \omega(j) \left(\log(c_{t,j}) - \chi \frac{(n^m_{t,j})^{1+\eta}}{1+\eta} - \chi \frac{(n^w_{t,j})^{1+\eta}}{1+\eta} - F \cdot \mathbb{1}_{[n^w_{t,j}>0]} \right)$$

where the expectation is taken with respect to the evolution of u_t, subject to the sequence of budget constraints:

$$c_{t,j}(1+\tau_c) + k_{t+1,j+1} = \begin{cases} (k_{t,j} + \Gamma_t)(1 + r_t(1-\tau_k)) + g_t + W^L_{t,j}, & \text{if } j < 65 \\ (k_{t,j} + \Gamma_t)(1 + r_t(1-\tau_k)) + g_t + \Psi_t, & \text{if } j \geq 65 \end{cases}$$

where W^L is the household labor income (and unemployment benefits in case wife doesn't work):

$$W^L_{t,j} = \left(W^{L,m}_{t,j} + W^{L,w}_{t,j} \right) \left(1 - \tau_{ss} - \tau_l \left(W^{L,m}_{t,j} + W^{L,w}_{t,j} \right) \right) + \left(1 - \mathbb{1}_{[n^w_{t,j}>0]} \right) T_t,$$

$W^{L,m}_{t,j}$ and $W^{L,w}_{t,j}$ are the labor incomes of the two household memebers:

$$W^{L,i}_{t,j} = \frac{n^i_{t,j} w_t e^{a_i + \gamma_{0\iota} + \gamma_{1\iota} e^i_{t,j} + \gamma_{2\iota}(e^i_{t,j})^2 + \gamma_{3\iota}(e^i_{t,j})^3 + u^i_{t,j}}}{1 + \tilde{\tau}_{ss}}, \quad i = m, w$$

which depend on the individual's fixed type a_i, experience $e^i_{t,j}$ (which we assume equals age for men) and productivity shock $u^i_{t,j}$.

To reformulate this household problem recursively, we divide the budget constraints by the technology level Z_t. Recall that with our normalization of Z_0 and K_0, we have $Z_t = Y_t$. Also, recall that on the balanced growth path, $\Gamma^z = \Gamma_t/Z_t$, $g^z = g_t/Z_t$, $\Psi^z = \Psi_t/Z_t$, $T^z = T_t/Z_t$, $w^z = w_t/Z_t$ and r_t must remain constant. We define $c^z_j = c_{t,j}/Z_t$ and $k^z_j = k_{t,j}/Z_t$ and conjecture that they do not depend on the calendar time t either. This allows us to rewrite the budget constraints as:

$$c_j^z(1+\tau_c) + k_{j+1}^z(1+\mu) = \begin{cases} \left(k_j^z + \Gamma^z\right)\left(1 + r(1-\tau_k)\right) + g^z + W_j^L, & \text{if } j < 65 \\ \left(k_j^z + \Gamma^z\right)\left(1 + r(1-\tau_k)\right) + g^z + \Psi^z, & \text{if } j \geq 65 \end{cases}$$

Substituting $c_{t,j} = c_j^z Z_t$ into the objective function, we get an additive term that depends only on the sequence of Z_t and drops out of the maximization problem, and finally get the recursive formulation stated in the main text.

9.3 Tax function

Given the tax function

$$ya = \theta_0 y^{1-\theta_1}$$

we employ, the average tax rate is defined as

$$ya = (1-\tau(y))y$$

and thus

$$\theta_0 y^{1-\theta_1} = (1-\tau(y))y$$

and thus

$$\begin{aligned} 1-\tau(y) &= \theta_0 y^{-\theta_1} \\ \tau(y) &= 1-\theta_0 y^{-\theta_1} \\ T(y) &= \tau(y)y = y - \theta_0 y^{1-\theta_1} \\ T'(y) &= 1-(1-\theta_1)\theta_0 y^{-\theta_1} \end{aligned}$$

Thus the tax wedge for any two incomes (y_1, y_2) is given by

$$1 - \frac{1-\tau(y_2)}{1-\tau(y_1)} = 1 - \left(\frac{y_2}{y_1}\right)^{-\theta_1} \tag{12}$$

and therefore independent of the scaling parameter θ_0. Thus by construction one can raise average taxes by lowering θ_0 and not change the progressivity of the tax code, since (as long as tax progressivity is defined by the tax wedges) the progressivity of the tax code[30] is uniquely determined by the parameter θ_1. Heathcote, Storesletten, and Violante (2012) estimate the parameter $\theta_1 = 0.18$ for all households. Above we let θ_1 vary by family type.

9.4 Estimation of Returns to Experience and Shock Processes From the PSID

We take the log of equation 5 and estimate a log(wage) equation using data from the non-poverty sample of the PSID 1968-1997. Equation 6 is estimated using the residuals from 5.

To control for selection into the labor market, we use Heckman's 2-step selection model. For people who are working and for which we observe wages, the wage depends on a 3rd order polynomial in age (men), t, or years of labor market experience (women), e, as well as dummies for the year of observation, D:

$$log(w_{it}) = \phi_i(constant + D_t'\zeta + \gamma_1 e_{it} + \gamma_2 e_{it}^2 + \gamma_3 e_{it}^3 + u_{it}) \tag{13}$$

Age and labor market experience are the only observable determinants of wages in the model apart from gender. The probability of participation (or selection equation) depends

[30]Note that

$$1 - \tau(y) = \frac{1 - T'(y)}{1 - \theta_1} > 1 - T'(y)$$

and thus as long as $\theta_1 \in (0, 1)$ we have that

$$T'(y) > \tau(y)$$

and thus marginal tax rates are higher than average tax rates for all income levels.

on various demographic characteristics, Z:

$$\Phi(participation) = \Phi(Z'_{it}\xi + \upsilon_{it}) \tag{14}$$

The variables included in Z are marital status, age, the number of children, years of schooling, time dummies, and an interaction term between years of schooling and age. To obtain the parameters, σ_{ι}, ρ_{ι} and $\sigma_{\alpha_{\iota}}$ we obtain the residuals $u_i t$ and use them to estimate the below equation by fixed effects estimation:

$$u_{it} = \alpha_i + \rho u_{it-1} + \epsilon_{it} \tag{15}$$

The parameters can be found in Table 2.

9.5 *Additional Tables and Figures*

Table 4: Tax Functions by Country and Family Type, OECD 2000-2007

Country	Married 0C		Married 1C		Married 2C		Single 0C	
	θ_0	θ_1	θ_0	θ_1	θ_0	θ_1	θ_0	θ_1
Austria	0.926427	0.150146	1.003047	0.198779	1.076124	0.23796	0.854448	0.175967
Canada	0.901481	0.155047	0.981109	0.228148	1.066354	0.296329	0.789222	0.147083
Denmark	0.787587	0.229954	0.874734	0.305302	0.920347	0.331685	0.690296	0.220311
Finland	0.868634	0.223116	0.92298	0.261043	0.976928	0.293236	0.763024	0.207634
France	0.917449	0.119957	0.944289	0.133912	1.019455	0.174277	0.85033	0.137575
Germany	0.892851	0.203455	0.956596	0.238398	1.022274	0.272051	0.77908	0.198354
Greece	1.060959	0.161687	1.088914	0.178131	1.127027	0.19963	1.019879	0.228461
Iceland	0.872072	0.194488	0.932844	0.243148	0.990471	0.287094	0.784118	0.153982
Ireland	0.946339	0.162836	1.101397	0.282089	1.187044	0.326003	0.85533	0.188647
Italy	0.900157	0.15939	0.949843	0.198573	1.00814	0.241968	0.822067	0.153275
Japan	0.948966	0.073769	0.971621	0.086518	0.992375	0.097036	0.916685	0.121497
Luxembourg	0.947723	0.15099	1.024163	0.190363	1.113409	0.231438	0.849657	0.163415
Netherlands	0.958121	0.219349	1.004174	0.245393	1.025102	0.256418	0.863586	0.272312
Norway	0.838322	0.148316	0.894721	0.194368	0.932718	0.218213	0.76396	0.146082
Portugal	0.948209	0.119169	0.97794	0.138682	1.009808	0.157309	0.882183	0.132277
Spain	0.923449	0.130171	0.93517	0.134039	0.949941	0.14052	0.862569	0.164186
Sweden	0.782747	0.166797	0.865716	0.240567	0.919471	0.276415	0.717018	0.217619
Switzerland	0.925567	0.116475	0.968531	0.136431	1.008289	0.15569	0.878904	0.128988
UK	0.908935	0.165287	0.994826	0.233248	1.049323	0.273376	0.836123	0.168479
US	0.873964	0.108002	0.940772	0.158466	1.006167	0.203638	0.817733	0.1106

Table 5: Distribution of households (with a head between 20 and 64 years of age) by the number of children and marital status, IPUMS USA, 2000-2007

		Marital status		
		Single	Married	Total
# of children	0	29.28	20.86	50.15
	1	7.49	13.27	20.76
	2	4.41	14.26	18.67
	3	1.65	5.81	7.46
	4	0.50	1.61	2.11
	5	0.14	0.42	0.56
	6	0.04	0.14	0.18
	7	0.01	0.05	0.07
	8	0.00	0.02	0.03
	9+	0.00	0.02	0.02
	Total	43.54	56.46	100.00

Table 6: Labor Income Taxes Paid by Income Deciles (benchmark calibration)

Income Decile	Share of Total	Cumulative Share
1	0.000	0.000
2	0.011	0.012
3	0.024	0.035
4	0.037	0.073
5	0.053	0.126
6	0.072	0.198
7	0.098	0.295
8	0.136	0.432
9	0.201	0.632
10	0.368	1.000

Table 7: Selected Statistics for Different Tax Progressivity at 17.5%, 25% and 35% Average Tax Rate as % of the US Benchmark

	$\bar{\tau}(y) = 17.5\%$			$\bar{\tau}(y) = 25\%$			$\bar{\tau}(y) = 35\%$		
	Flat tax	US Prog.	2X US Prog.	Flat tax	US Prog.	2X US Prog.	Flat tax	US Prog.	2X US Prog.
	Flat tax	US Prog.	2X US Prog	Flat tax	US Prog.	2X US Prog	Flat tax	US Prog.	2X US Prog
Tax Revenue	104.8	100.0	93.9	123.1	117.9	110.3	143.8	136.5	127.5
θ_0	0.927	1.000	1.056	0.843	0.907	0.955	0.729	0.783	0.822
Labor Supply	103.8	100.0	94.9	97.2	94.7	89.6	89.5	86.0	81.9
Labor supply in Efficiency Units	104.7	100.0	93.9	99.8	95.7	89.6	93.7	89.1	83.3
Male Labor Supply	103.6	100.0	95.5	101.7	98.0	93.6	98.7	95.3	90.8
Single Male Labor Supply	102.8	100.0	96.5	100.8	98.0	94.6	97.6	95.1	91.8
Married Male Labor Supply	104.0	100.0	95.0	102.2	98.1	93.1	99.2	95.4	90.3
Female Labor Supply	104.2	100.0	94.1	90.7	89.9	84.1	76.5	73.0	69.2
Single Female Labor Supply	90.7	100.0	110.3	73.5	88.4	98.1	59.9	68.8	80.0
Married Female Labor Supply	113.6	100.0	82.8	102.7	91.0	74.3	88.1	75.9	61.7
Female LFP	97.6	100.0	101.8	88.1	93.3	94.4	77.5	79.5	82.4
Single Female LFP	87.0	100.0	116.1	73.7	92.1	107.3	63.5	76.0	92.6
Married Female LFP	105.0	100.0	91.7	98.1	94.2	85.4	87.3	82.0	75.2
Female Intensive Margin	106.7	100.0	92.4	103.0	96.3	89.0	98.7	91.8	84.0
Single Female Intensive Margin	104.2	100.0	95.0	99.8	96.0	91.4	94.3	90.5	86.4
Married Female Intensive Margin	108.1	100.0	90.2	104.7	96.6	87.0	100.9	92.6	82.0
Savings	106.7	100.0	92.3	98.4	92.8	85.8	88.6	83.3	77.1

Column 3 is the US bechmark calibration.

Table 8: Selected Statistics for Different Tax Progressivity at Fixed θ_0 as % of the US Benchmark

	$\theta_0 = \theta_{0US}$			$\theta_0 = 0.907 * \theta_{0US}$			$\theta_0 = 0.7825 * \theta_{0US}$		
	Flat tax	US Prog.	2X US Prog.	Flat tax	US Prog.	2X US Prog.	Flat tax	US Prog.	2X US Prog.
Average Tax Rate	11.1%	17.5%	21.7%	19.3%	25.0%	28.6%	30.3%	35.0%	38.0%
Tax Revenue	86.0	100.0	103.4	109.3	117.9	117.2	134.5	136.5	131.5
Labor Supply	108.5	100.0	92.1	102.4	94.7	86.9	93.0	86.0	79.3
Labor supply in Efficiency Units	108.3	100.0	91.6	103.6	95.7	87.4	96.6	89.1	35.2
Male Labor Supply	105.3	100.0	94.5	103.2	98.0	92.6	100.2	95.3	77.7
Single Male Labor Supply	104.6	100.0	95.5	102.3	98.0	93.6	99.2	95.1	114.2
Married Male Labor Supply	105.6	100.0	94.0	103.6	98.1	92.1	100.7	95.4	89.5
Female Labor Supply	113.0	100.0	88.8	101.2	89.9	78.8	82.9	73.0	64.3
Single Female Labor Supply	100.9	100.0	104.2	86.9	88.4	91.6	65.9	68.8	73.3
Married Female Labor Supply	121.4	100.0	78.0	111.2	91.0	84.3	94.7	75.9	57.9
Female LFP	102.5	100.0	98.0	95.7	93.3	90.2	82.0	79.5	78.0
Single Female LFP	92.9	100.0	112.0	84.2	92.1	102.0	67.8	76.0	86.4
Married Female LFP	109.3	100.0	88.2	103.7	94.2	81.9	92.0	82.0	72.1
Female Intensive Margin	110.2	100.0	90.6	105.8	96.3	87.4	101.1	91.8	82.4
Single Female Intensive Margin	108.6	100.0	93.0	103.2	96.0	89.8	97.2	90.5	84.9
Married Female Intensive Margin	111.1	100.0	88.4	107.2	96.6	102.9	103.0	92.6	80.4
Savings	113.7	100.0	88.7	104.7	92.8	82.6	93.2	83.3	74.5

Column 3 is the US bechmark calibration.

Table 9: Parameters Calibrated Endogenously (Germany)

Parameter	Value	Description	Moment	Moment Value
γ_{0m}		$w_t(a_i, e_i, u_i) = w_t e^{a_i+\gamma_{0w}+\gamma_{1w}e_i+\gamma_{2w}e_i^2+\gamma_{3w}e_i^3+u_i}$	Gender earnings ratio	2.081
β		Discount factor	K/Y	2.640
$\mu_{F^{Mw}}$		$F^{Mw} \sim N(\mu_{F^{Mw}}, \sigma^2_{F^{Mw}})$	Married fem employment	0.540
$\sigma_{F^{Mw}}$		$U^M(c, n^m, n^w) = \log(c) - \chi^{Mm}\frac{(n^m)^{1+\eta^m}}{1+\eta^m} -$	R^2 from $\mathbb{1}_{[n_t>0]} = \rho_0 + \rho_1 \mathbb{1}_{[n_{t-1}>0]}$	0.512
χ^{Mw}		$\chi^{Mw}\frac{(n^w)^{1+\eta^w}}{1+\eta^w} - F^{Mw} \cdot \mathbb{1}_{[n^w>0]}$	Married female hours	0.171 (933 h/year)
χ^{Mm}			Married male hours	0.340 (1855 h/year)
$\mu_{F^{Sw}}$		$F^{Sw} \sim N(\mu_{F^{Sw}}, \sigma^2_{SMw})$	Single fem. employment	0.586
$\sigma_{F^{Sw}}$		$U^S(c, n, \iota) = \log(c) - \chi^{S\iota}\frac{(n)^{1+\eta^\iota}}{1+\eta^\iota}$	R^2 from $\mathbb{1}_{[n_t>0]} = \rho_0 + \rho_1 \mathbb{1}_{[n_{t-1}>0]}$	0.420
χ^{Sw}		$-F^{S\iota} \cdot \mathbb{1}_{[n>0]}$	Single female hours	0.239 (1303 h/year)
χ^{Sm}			Single male hours	0.296 (1616 h/year)

Table 10: Parameters Calibrated Outside of the Model (Germany)

Parameter	Value	Description	Target
$1/\eta^m, 1/\eta^w$	0.4, 0.8	$U^M(c, n^m, n^w) = \log(c) - \chi^{Mm}\frac{(n^m)^{1+\eta^m}}{1+\eta^m} - \chi^{Mw}\frac{(n^w)^{1+\eta^w}}{1+\eta^w} - F^{Mw} \cdot \mathbb{1}_{[n^w>0]}$	Literature
$\gamma_{1m}, \gamma_{2m}, \gamma_{3m}$	0.067, -0.003, $3.7 * 10^{-5}$	$w_t(a_i, e_i, u_i) = w_t e^{a_i+\gamma_{0m}+\gamma_{1m}e_i+\gamma_{2m}e_i^2+\gamma_{3m}e_i^3+u_i}$	GSOEP (1984-1997)
$\gamma_{1w}, \gamma_{2w}, \gamma_{3w}$	0.167, -0.003, $2.5 * 10^{-5}$	$w_t(a_i, e_i, u_i) = w_t e^{a_i+\gamma_{0w}+\gamma_{1w}e_i+\gamma_{2w}e_i^2+\gamma_{3w}e_i^3+u_i}$	
$\sigma_m, \sigma_w,$	0.253, 0.264	$u' = \rho_{jg}u + \epsilon$	
ρ_m, ρ_w	0.036, 0.061	$\epsilon \sim N(0, \sigma_{jg}^2)$	
σ_{am}, σ_{aw}	0.546, 0.366	$a_\iota \sim N(0, \sigma_{a_m}^2)$	
$\theta_0^S, \theta_1^S, \theta_0^{M0}, \theta_1^{M0}$	0.779, 0.198, 0.892, 0.203	$ya = \theta_0 y^{1-\theta_1}$	OECD tax data
$\theta_0^{M1}, \theta_1^{M1}, \theta_0^{M2}, \theta_1^{M2}$	0.957, 0.238, 1.022, 0.272	$ya = \theta_0 y^{1-\theta_1}$	
τ_k	0.23	Capital tax	Trabandt and Uhlig (2011)
$\tau_{ss}, \tilde{\tau}_{ss}$	0.171, 0.176	Social Security tax	OECD
τ_c	0.15	Consumption tax	Trabandt and Uhlig (2011)
T	$0.2018 \cdot AW$	Income if not working	
G/Y	0.0725	Pure public consumption goods	2X military spending (World Bank)
B/Y	0.4124	National debt	Government debt (World Bank)
$\omega(j)$	Varies	Survival probabilities	NCHS
$M(j)$, $D(j)$	Varies	Marriage and divorce probabilities	IPUMS
$\Xi(x, j)$	Varies	Distribution of children	GSOEP
$\Upsilon(x, x', j)$	Varies	Transition probabilities # of children	GSOEP
k_0		Savings at age 20	
μ	0.0200	Output growth rate	Trabandt and Uhlig (2011)
δ	0.0788	Depreciation rate	$I/K - \mu$ (BEA)

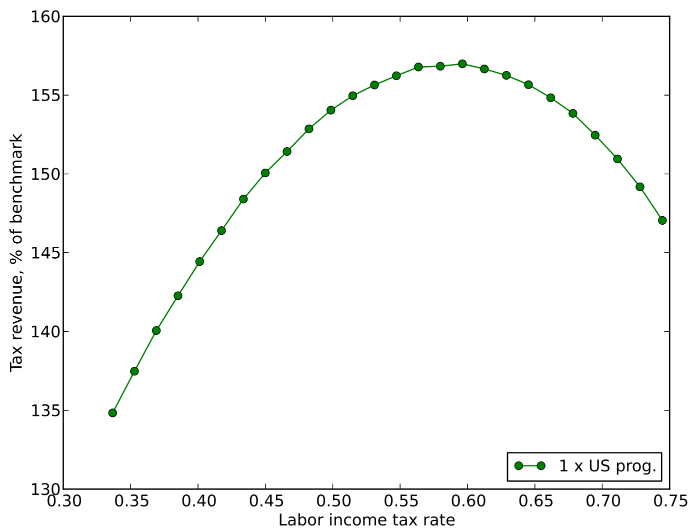

Figure 9: The g-Laffer Curve for US Tax Progressivity (using 15 different fixed costs of labor force participation)

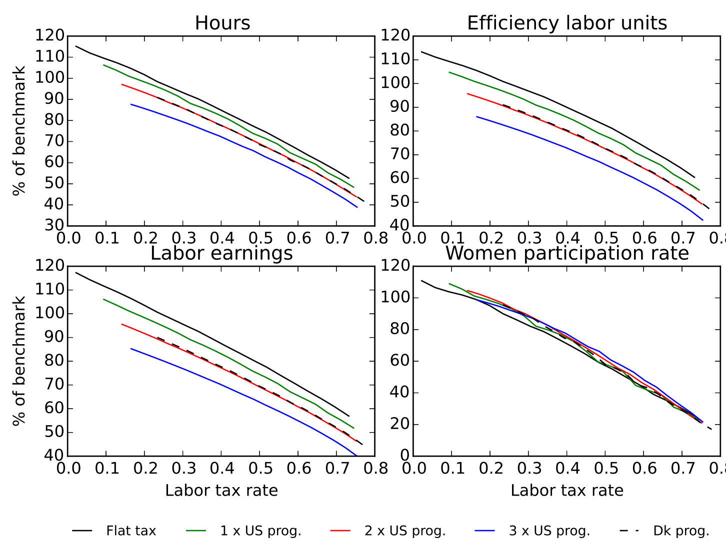

Figure 10: LFP by Tax Progressivity and Level for g-Laffer Curves

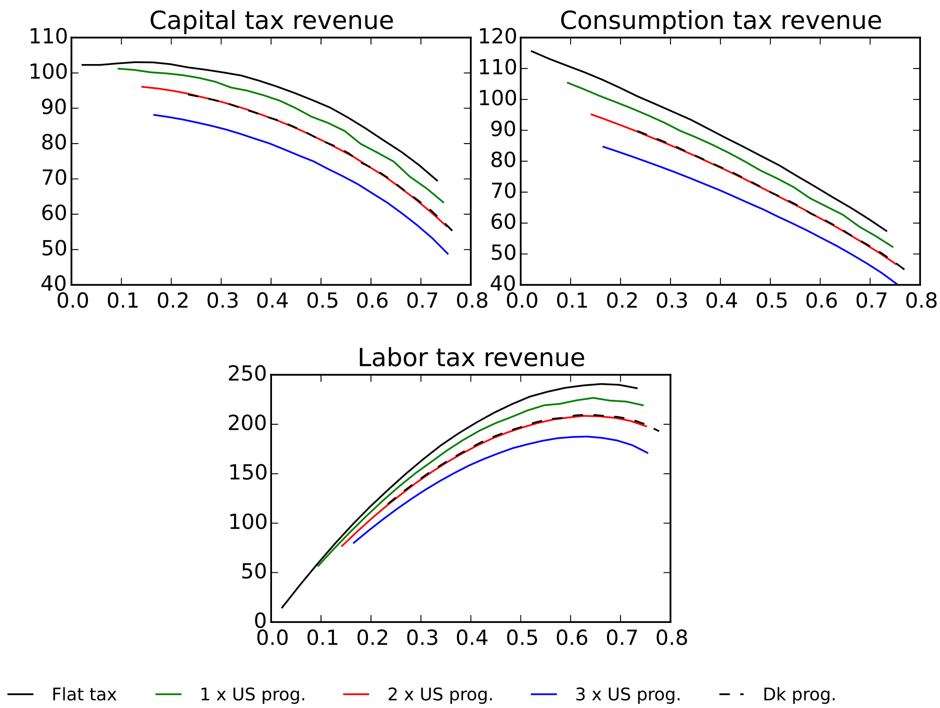

Figure 11: The Impact of Tax Progressivity on Revenue From Labor-, Consumption- and Capital Taxes

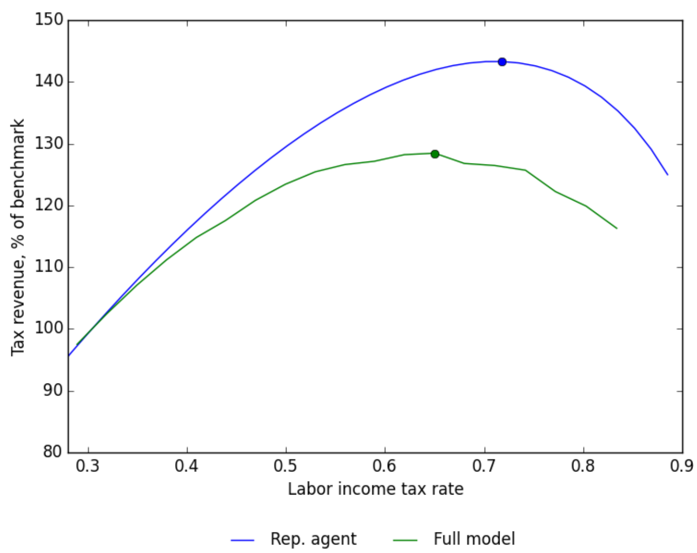

Figure 12: Laffer Curves for the Full Model and a Rep. Agent Model With Equivalent Labor Supply Elasticity After a 1-Period Productivity Shock ($1/\eta = 0.491$).

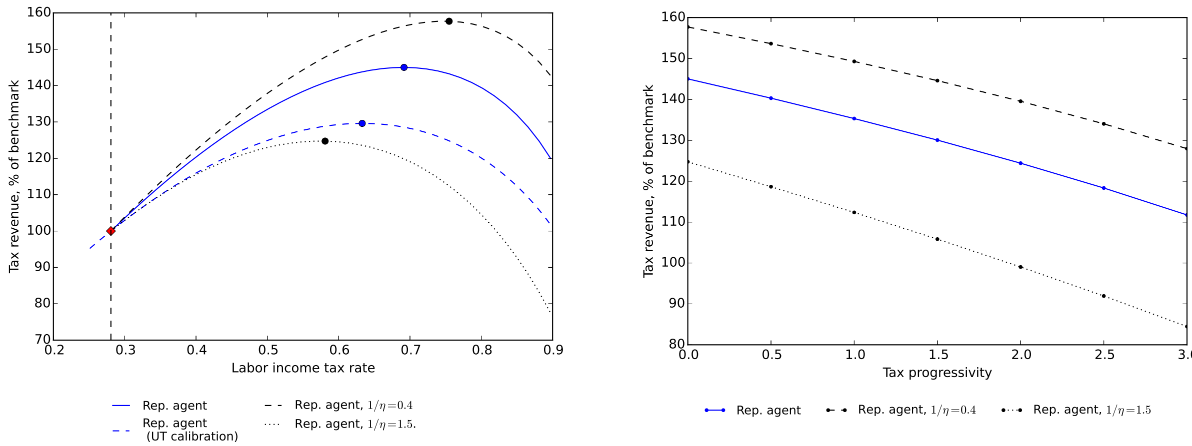

Figure 13: Laffer Curves for the Rep. Agent Model with Different Labor Supply Elasticities (left). The Impact of Progressivity on Maximum Revenue in the Rep. Agent Model with Different Labor Supply Elasticites (right).

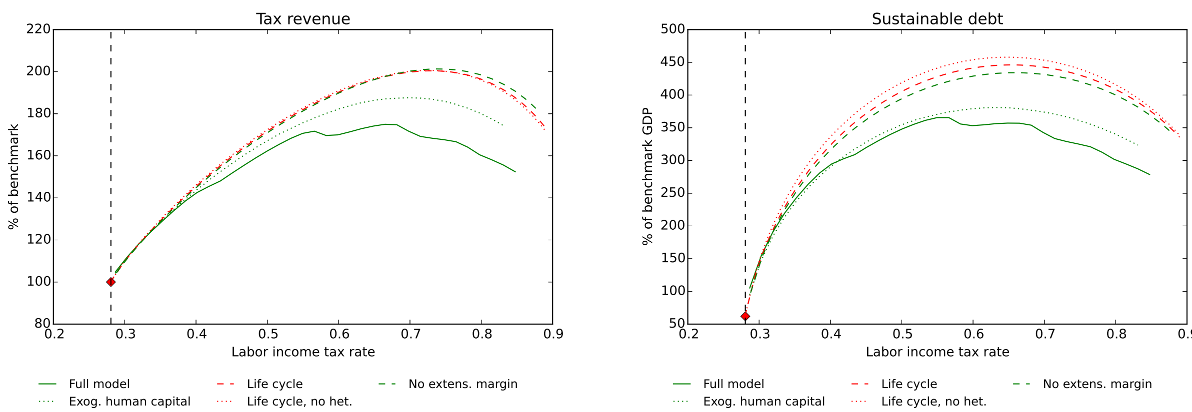

Figure 14: Laffer Curves and Maximum Sustainable Debt for Flat Taxes in Different Models

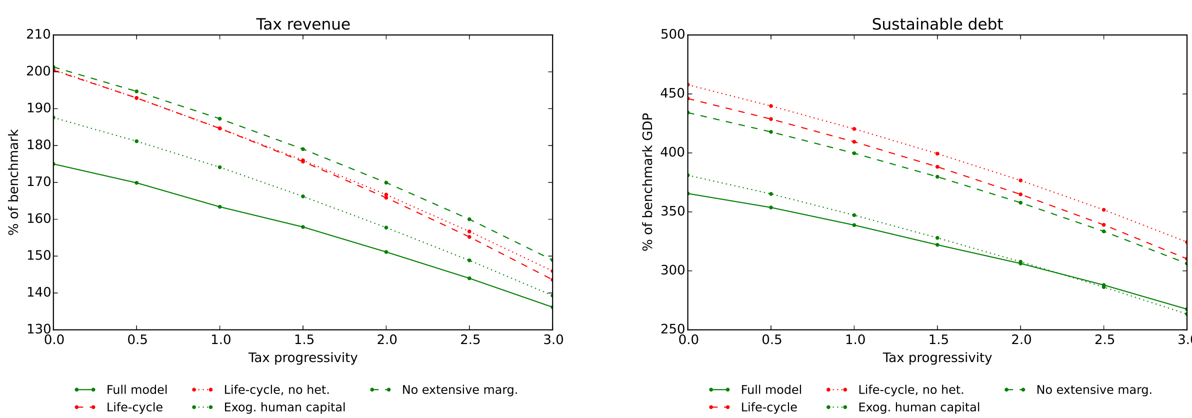

Figure 15: The Impact of Progressivity on Maximum Revenue and Sustainable Debt in Different Models

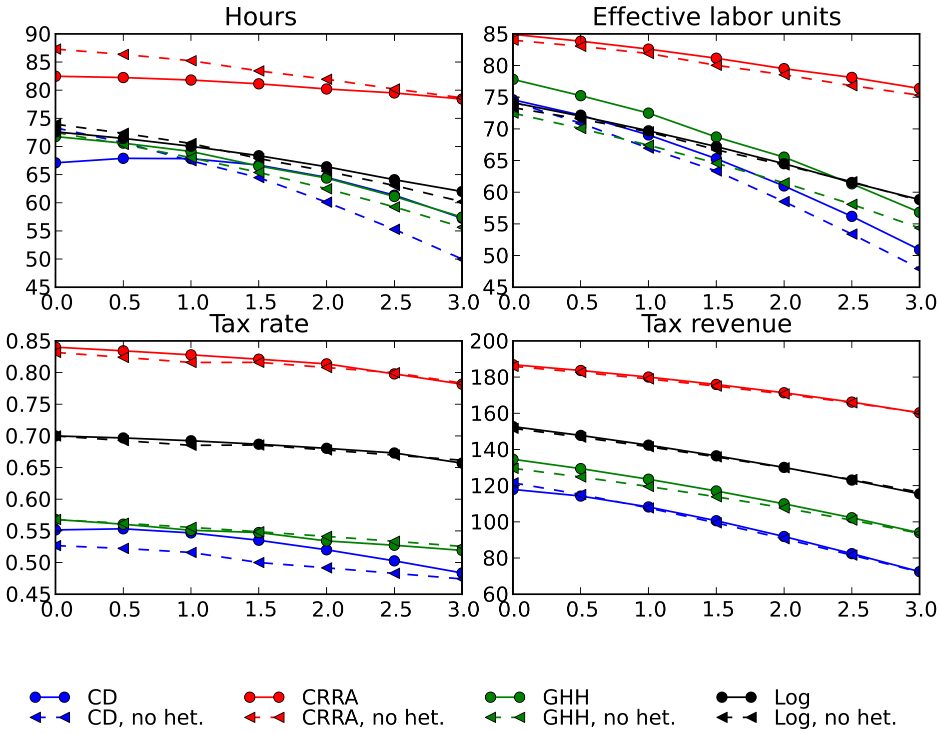

Figure 16: The Impact of Tax Progressivity for Different Utility Functions

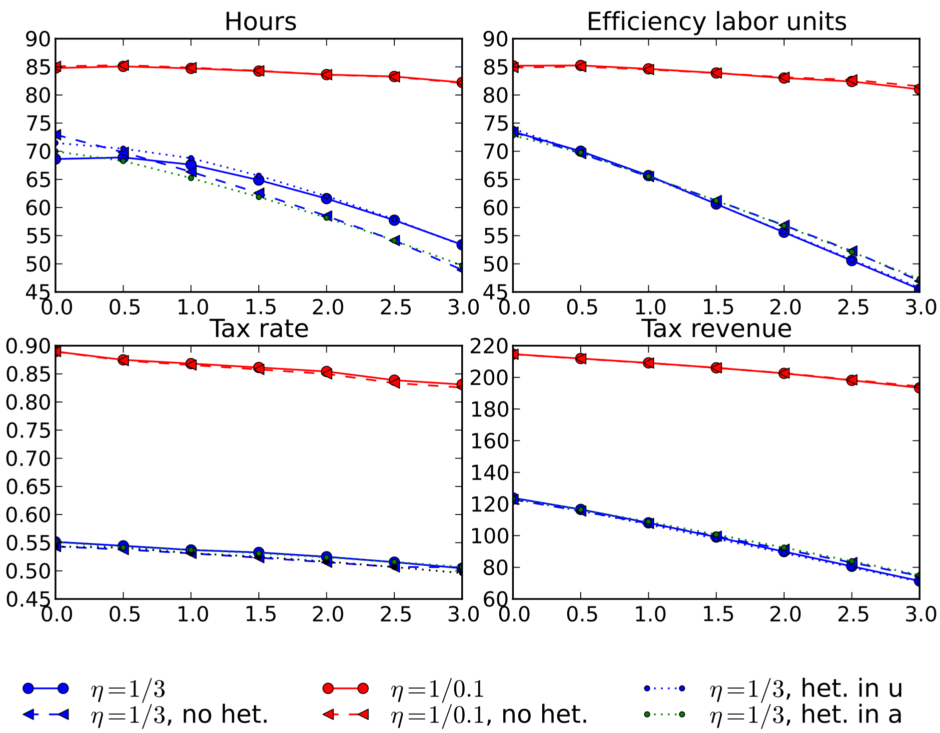

Figure 17: The Impact of Tax Progressivity for Different Labor Supply Elasticities

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