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“How Does Tax Progressivity and Household Heterogeneity Affect Laffer Curves?”

by

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# How Does Tax Progressivity and Household Heterogeneity Affect Laffer Curves?\*

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## Abstract

The recent public debt crisis in most developed economies implies an urgent need for increasing tax revenues or cutting government spending. In this paper we study the importance of household heterogeneity and the progressivity of the labor income tax schedule for the ability of the government to generate tax revenues. 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. We calibrate the model to macro, micro and tax data from the US as well as a number of European countries, and then for each country characterize the labor income tax Laffer curve under the current country-specific choice of the progressivity of the labor income tax code. 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 7%. We also find that modeling household heterogeneity is important for the shape of the Laffer curve.

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

**JEL:** E62, H20, H60

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# 1 Introduction

The recent public debt crisis in many developed economies with soaring debt-to-GDP ratios leaves governments around the world with two (not mutually exclusive) options: to increase tax revenues or reduce government expenditures. In this paper we revisit the questions whether, and to what extent, increasing tax revenues is even an option for specific countries? We argue that the country-specific extent of household inequality in labor earnings and wealth as well as the progressivity of the income tax code are crucial determinants of the Laffer curve and thus the maximal tax revenue (determined by the peak of the Laffer curve) a country can generate.

The shape of the labor income tax schedule varies greatly across countries (see Section 2), perhaps due to country-specific tastes for redistribution and social insurance. We take the progressivity of the labor income tax schedule as well as the other forces that shape the income and wealth distribution in a specific country as given, and ask the question how the progressivity of the labor income tax code and the income and wealth distribution affect the maximal tax revenues that can be raised in the US and a number of European countries.

In order to answer this question 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 (extensive margin), how many hours to work conditional on participation (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 information on country-specific labor income tax progressivity measures, wage data and debt-to-output ratios when applying the model to other countries. Because of these cross-national differences the resulting Laffer curves, which

we deduce from the model by varying the *level* of labor income taxes, but holding their *progressivity* constant, display cross-country heterogeneity. We also document the importance of the shape of the labor income tax code for the peak of the Laffer curve for *each* country by tracing out how maximal tax revenues depend on a summary statistic that describes how progressive the tax code is.<sup>1</sup>

The idea that total tax revenues are a single-peaked function of the level of tax rates 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 infinitely lived representative agents, 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 labor supply choice as well as endogenous human

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<sup>1</sup>This exercise varies tax progressivity but holds the debt burden and the stochastic wage process constant, whereas the cross-country comparisons compare economies that differ simultaneously in their tax schedule, their debt burden and their wage processes.

capital accumulation, the degree of tax progressivity not only significantly changes the location of the peak of the Laffer curve for a given country, but implies much more substantial differences in that location *across countries* than suggested by Trabandt and Uhlig (2011)'s analysis.

Why and how does the degree of tax progressivity matters 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 for response of tax revenues on the level of taxes. On the positive side, the presence of an extensive margin typically leads to 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. However, in a life-cycle model the presence of labor market risk will lead to higher labor supply elasticity for older agents due to precautionary motives for younger agents, see Conesa, Kitao, and Krueger (2008). 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 meaning-

ful 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). 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.

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 concerned with the impact of the progressivity of the income tax code on the Laffer curve.

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 contains a cross-country analysis. 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 the OECD

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 used by Heathcote, Storesletten, and Violante (2012) who argue that it fits the U.S. data well<sup>2</sup>. Let  $y$  denote pre-tax (labor) income and  $ya$  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  $\theta_0$  and  $\theta_1$  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. Wedge based measures of progressivity are common in the literature. In this paper, we adopt the following tax progressivity wedge, where  $\tau(y)$  is the average tax rate: from:

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

This measure always takes a value between 0 and 1 and increases with the increase in the marginal tax rate  $\tau$  as earnings increases from  $y_1$  to  $y_2$ . If there is a flat tax, then the progressivity wedge would be zero for all levels of  $y_1$  and  $y_2$ . Analogous progressivity measures are used by Guvenen, Kuruscu, and Ozkan (2009) and Caucutt, Imrohoroglu, and Kumar (2003).

In Guvenen, Kuruscu, and Ozkan (2009)  $\tau(y)$  is the marginal tax rate. Using the average tax rate has two advantages. Firstly it makes the measure more robust.

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<sup>2</sup>see Appendix 9.3 for more details.

Guner, Kaygusuz, and Ventura (2012) show that if the tax schedule is approximated by a polynomial one will do relatively well in approximating the average tax rate at different incomes and worse in approximating the marginal tax rate. The marginal tax rate experiences sudden jumps and the average tax rate does not. Secondly for our tax function tax-progressivity is uniquely determined by the parameter  $\theta_1$ , see Section 9.3. One can increase the tax level while keeping tax progressivity constant for all levels of  $y_1$  and  $y_2$  just by changing  $\theta_0$ .

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 1 for singles without children and married couples with 0,1, and 2 children (the household types which we will have in the model in Section 3). We then take the sum of the estimated  $\theta_1$ s weighted by each family type's share of the population in the US<sup>3</sup>. Table 1 displays the progressivity index for the US, Canada, Japan, and all

<sup>3</sup>In the model we assume that singles do not have children and that the maximum number of children is 2. We therefore give  $\theta_1$  for singles without children the population weight of all singles



the countries in Western Europe.

We observe that there is considerable cross-country variation in tax-progressivity. The flattest taxes are in Japan and the most progressive taxes in Denmark. As measured by the index, taxes in Denmark are about 2.5 times more progressive than in Japan<sup>4</sup>. The US is among the countries with flattest taxes.

### 3 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:

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

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  $\delta$  is the capital depreciation rate.

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and  $\theta_1$  for married couples the population weight of married couples with 2 or more children.

<sup>4</sup>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 highest debt to GDP ratio.

We assume that  $Z_t$ , the labour-augmenting productivity parameter, grows deterministically at rate  $\mu$ :

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

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  $\mu^5$ . 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:

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

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

We restrict our analysis to balanced growth equilibria (in which long-run growth is generated by 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.

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<sup>5</sup>See King, Plosser, and Rebelo (2002).

### 3.2 Demographics

The economy is populated by  $J$  overlapping generations of finitely lived households. There are 5 types of households; single males, single females, and married couples with  $x \in \{0, 1, 2\}$  children<sup>6</sup>. We assume that within the same married household, the husband and the wife are of the same age. All households start life at age 25 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. 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.

Let  $j$  denote the household's age. 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 age 100.<sup>7</sup> A husband and a wife both die at the same age. A model period is 1 year, so there are a total of 40 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 hetero-

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<sup>6</sup>In our model, children only influence the taxes that a household needs to pay. 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.

<sup>7</sup>This means that  $J = 76$ .

geneous 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 works 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 supply decisions but receive a social security payment,  $\Psi_t$ .

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  $\Gamma$  to denote the per-household bequest.

### 3.3 Labor Income

The wage of an individual depends on the 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,  $a_\iota \sim N(0, \sigma_{a_\iota}^2)$ , 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 (of course the realization of this shock is not common to all households). Thus, the wage of an individual  $i$  is given by:

$$w^z(a_i, e_i, u_i) = w^z e^{a_i + \gamma_{0\iota} + \gamma_{1\iota} e_i + \gamma_{2\iota} e_i^2 + \gamma_{3\iota} e_i^3 + u_i} \quad (5)$$

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

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

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

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

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

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  $\tau_{ss}$  and  $\tilde{\tau}_{ss}$  and pays benefits,  $\Psi_t$ , 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,  $rB_t$ , and 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 assumed to be proportional to GDP. Consumption and capital income are taxed at flat rates  $\tau_c$ , and  $\tau_k$ . 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  $\theta_0$  and  $\theta_1$  govern the level and the progressivity of the tax code, respectively.<sup>8</sup> Heathcote, Storesletten, 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.

In a BGP with constant tax rates, the ratio of government revenues to output will remain constant.  $G_t$ ,  $g_t$ ,  $\Psi_t$  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<sup>9</sup> that work 0 hours by  $\zeta_t$ , we can write the government budget

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<sup>8</sup>A further discussion of the properties of this tax function is provided in the appendix

<sup>9</sup>Recall that we assume that men always work.

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 in 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.

### ***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 males's experience is always equal to his age,  $e^m = j$ . The state space for a single household is  $(k, e, u, a, \iota, j)$ .

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 in 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:

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

s.t.:

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

$$Y^L = (Y^{L,m} + Y^{L,w})(1 - \tau_{ss} - \tau_l^M(x)(Y^{L,m} + Y^{L,w})) + (1 - 1_{[n^w > 0]})T$$

$$Y^{L,\iota} = \frac{n^\iota w^{z,\iota}(a^\iota, e^\iota, u^\iota)}{1 + \tilde{\tau}_{ss}}, \quad \iota = m, w$$

$$(e^m)' = e^m + 1, \quad (e^w)' = e^w + 1_{[n^w > 0]},$$

$$n^m \in (0, 1], \quad n^w \in [0, 1], \quad (k^z)' \geq 0, \quad c^z > 0,$$

$$n^\iota = 0 \quad \text{if } j \geq 65, \quad \iota = m, w.$$

$Y^L$  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,  $\tau_{ss}$  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:

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

s.t.:

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

$$Y^L = (Y^{L, \iota}) (1 - \tau_{ss} - \tau_l^S(Y^{L, \iota})) + (1 - 1_{[n^w > 0]}) T$$

$$Y^{L, \iota} = \frac{n^\iota w^{z, \iota} (a^\iota, e^\iota, u^\iota)}{1 + \tilde{\tau}_{ss}}, \quad \iota = m, w$$

$$(e^m)' = e^m + 1, \quad (e^w)' = e^w + 1_{[n^w > 0]},$$

$$n^m \in (0, 1], \quad n^w \in [0, 1], \quad (k^z)' \geq 0, \quad c^z > 0,$$

$$n^\iota = 0 \quad \text{if } j \geq 65, \quad \iota = m, w.$$

### 3.7 Recursive Competitive Equilibrium

We call an equilibrium of the growth adjusted economy a stationary equilibrium.<sup>10</sup>

Let  $\Phi^M(k^z, e^m, e^w, u^m, u^w, a^m, a^w, x, j)$  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.

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<sup>10</sup>the associated BGP can of course trivially be constructed by scaling all appropriate variables by the growth factor  $Z_t$ .

2. Markets clear:

$$\begin{aligned}
K^z + B^z &= \int k^z d\Phi^M + \int k^z d\Phi^M \\
L^z &= \int (n^m w^{zm} + n^w w^{zf}) d\Phi^M + \int (nw^z) d\Phi^S \\
\int c^z d\Phi^M + \int c^z d\Phi^S + (\mu + \delta)K^z + G^z &= (K^z)^\alpha (L^z)^{1-\alpha}
\end{aligned}$$

3. The factor prices satisfy:

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

4. The government budget balances:

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

5. The social security system balances:

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

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 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 approach.

### 4.1 Preferences

The momentary utility functions are given in equation 7 and 8. The discount factor,  $\beta$ , the means and variances of the fixed costs of working,  $\mu_{FMw}$ ,  $\mu_{FSw}$ ,  $\sigma_{FMw}^2$  and  $F^{Sw}$ , and the disutilities of working more hours,  $\chi^{Mm}$ ,  $\chi^{Mw}$ ,  $\chi^{Sm}$  and  $\chi^{Sw}$ , are among the estimated parameters. 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)<sup>11</sup>, 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

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<sup>11</sup>measured as the  $R^2$  from regressing this year's participation status on last year's participation status

rates, see Keane and Rogerson (2012).

## **4.2 Technology**

In line with contemporary literature, we set the capital share parameter,  $\alpha$ , 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,  $\rho_\iota$  and  $\sigma_\iota$ , and the variance of individual abilities,  $\sigma_{\alpha_\iota}$ , by fixed effects estimation. We normalize the parameter,  $\gamma_{0w}$  to 1 and calibrate the parameter  $\gamma_{0m}$ , 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 labor income tax data from the OECD to estimate the parameters  $\theta_0$  and  $\theta_1$  for different family types. Table 4 in the Appendix summarizes our findings.

We assume that the social security contributions for the employee,  $\tau_{SS}$ , 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  $\tau_{SS}$  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  $t$  by  $M_t$  and  $D_t$ , we compute the probability of getting married at age  $t$ ,  $\bar{\omega}(t)$  and the probability of getting divorced,  $\pi(t)$ , from the following transition equations:

$$\begin{aligned} M_{t+1} &= (1 - M_t)\bar{\omega}(t) + M_t(1 - \pi(t)), \\ D_{t+1} &= D_t(1 - \bar{\omega}(t)) + M_t\pi(t). \end{aligned}$$

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

Table 2: Parameters Calibrated Outside of the Model

Parameter	Value	Description	Target
$1/\eta^m, 1/\eta^w$	0.4, 0.8	$U^M(c, n^m, n^w) = \log(c) - \chi^{Mm} \frac{(n^m)^{1+\eta^m}}{1+\eta^m} - \chi^{Mw} \frac{(n^w)^{1+\eta^w}}{1+\eta^w} - F^{Mw} \cdot 1_{[n^w > 0]}$	Literature
$\gamma_{1m}, \gamma_{2m}, \gamma_{3m}$	$0.109, -1.47 * 10^{-3}, 6.34 * 10^{-6}$	$w_t(a_i, e_i, u_i) = w_t e^{a_i + \gamma_{0m} + \gamma_{1m} e_i + \gamma_{2m} e_i^2 + \gamma_{3m} e_i^3 + u_i}$	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	$u' = \rho_{jg} u + \epsilon$	OECD tax data
$\rho_m, \rho_w$	0.396, 0.339	$\epsilon \sim N(0, \sigma_{jg}^2)$	
$\sigma_{am}, \sigma_{aw}$	0.338, 0.385	$a_t \sim N(0, \sigma_{am}^2)$	
$\theta_0^S, \theta_1^S, \theta_0^{M0}, \theta_1^{M0}$	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	$ya = \theta_0 y^{1-\theta_1}$	
$\tau_k$	0.36	Capital tax	Trabandt and Uhlig (2011)
$\tau_{ss}, \tilde{\tau}_{ss}$	(0.0765, 0.0765)	Social Security tax	OECD
$\tau_c$	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
$k_0$	$0.4409 \cdot AW$	Savings at age 20	NLSY97
$\mu$	0.0200	Output growth rate	Trabandt and Uhlig (2011)
$\delta$	0.0788	Depreciation rate	$I/K - \mu$ (BEA)

Table 3: Parameters Calibrated Endogenously

Parameter	Value	Description	Moment	Moment Value
$\gamma_{0m}$	-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
$\beta$	1.008	Discount factor	K/Y	2.640
$\mu_{F^{Mw}}$	-0.061	$U^M(c, n^m, n^w) = \log(c) - \chi^{Mm} \frac{(n^m)^{1+\eta^m}}{1+\eta^m} -$	Married fem employment	0.676
$\sigma_{F^{Mw}}$	0.188	$\chi^{Mw} \frac{(n^w)^{1+\eta^w}}{1+\eta^w} - F^{Mw} \cdot 1_{[n^w>0]}$	$R^2$ from $1_{[n_t>0]} = \rho_0 + \rho_1 1_{[n_{t-1}>0]}$	0.553
$\chi^{Mw}$	4.520		Married female hours	0.224 (1225 h/year)
$\chi^{Mm}$	21.520		Married male hours	0.360 (1965 h/year)
$\mu_{F^{Sw}}$	-0.027	$U^S(c, n, \iota) = \log(c) - \chi^{S\iota} \frac{(n)^{1+\eta^\iota}}{1+\eta^\iota}$	Single fem. employment	0.760
$\sigma_{F^{Sw}}$	0.227	$-F^{S\iota} \cdot 1_{[n>0]}$	$R^2$ from $1_{[n_t>0]} = \rho_0 + \rho_1 1_{[n_{t-1}>0]}$	0.463
$\chi^{Sw}$	8.700		Single female hours	0.251 (1371 h/year)
$\chi^{Sm}$	66.300		Single male hours	0.282 (1533 h/year)

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 lumpsum to households.

#### 4.7 Estimation Method

Four 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  $V(\Theta) = (V_1(\Theta), \dots, V_{10}(\Theta))'$  denote the vector where  $V_i(\Theta) = (\bar{m}_i - \hat{m}_i(\Theta))/\bar{m}_i$  is the percentage difference be-

tween 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 consisely describes our counterfactual experiements in Sections 6 and 7. We start by calibrating the model to data from each of the countries that we consider. 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:

1. For a given model and given progressivity of the tax code defined by the parameter  $\theta_1$  we derive the Laffer curve by scaling up the tax level (as measured by  $\theta_0$ ) for all family types by the same constant and plotting BGP tax revenue against the level of taxes  $\theta_0$ . 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  $\theta_1$ . 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. 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, thereby also characterizing the maximal sustainable stock of U.S. government debt.



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  $\theta_1$ , 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 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 revenue-maximizing tax levels and associated maximal tax (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 and thus inequality 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. wage heterogeneity facts to the German tax code, and then by also inserting a "German" wage process into the model (that is, by re-calibrating the model fully to German micro data).

## 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 we assume that the increase in revenue is redistributed evenly to all households. In the second specification, we assume that the increase in revenue is spent on paying interest on debt.

We find that more progressive taxes significantly reduce tax revenues (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 US Laffer curves under the assumption that the increase in revenue is redistributed lumpsum to all households. This is similar to Trabandt and Uhlig (2011). We vary the progressivity of the labor income tax schedule, as defined by 2, by multiplying  $\theta_1$  for all family types by the same constant and we change the tax level while holding progressivity constant by multiplying  $\theta_0$  for all family types by the same constant.

In Figure 1, 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 55% if the average labor income tax level is raised from 17% today to about 55%. 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<sup>12</sup>.

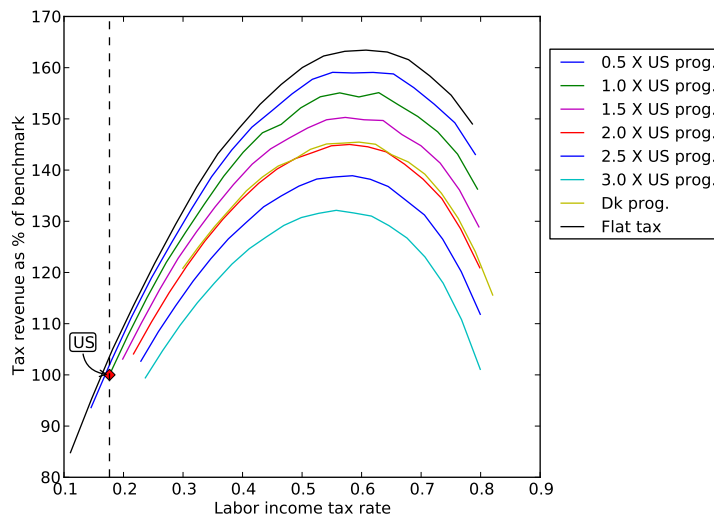


Figure 1: The Impact of Tax Progressivity the Laffer Curve (holding debt to GDP constant)

## 6.2 The Impact of Progressivity on Sustainable Debt

In Figure 2, we plot Laffer curves for our simulated US economy under the assumption that the increase in revenue is spent 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.

As we would expect the peak of the Laffer curve is higher when we instead of redistributing revenues spend them on paying off debt. 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

<sup>12</sup>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 get a system with progressivity exactly equal to the Danish system. The two tax systems also differ with respect to how hard they tax different family types.

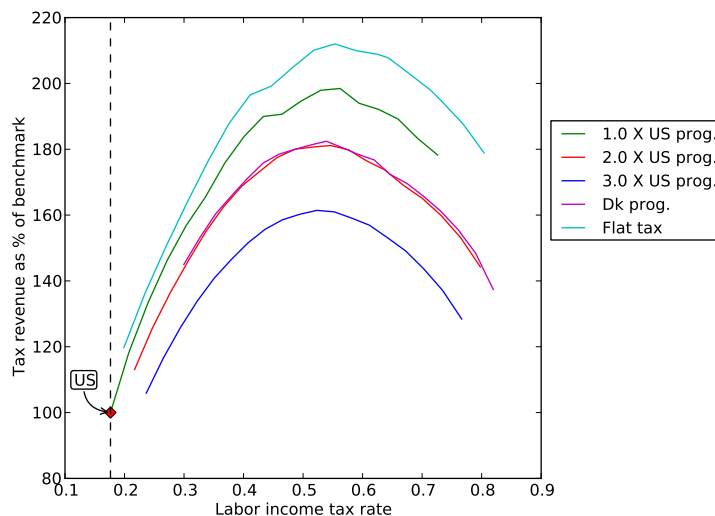


Figure 2: The impact of progressivity on the laffer curve when new revenues are used for paying interest on debt (closed economy)

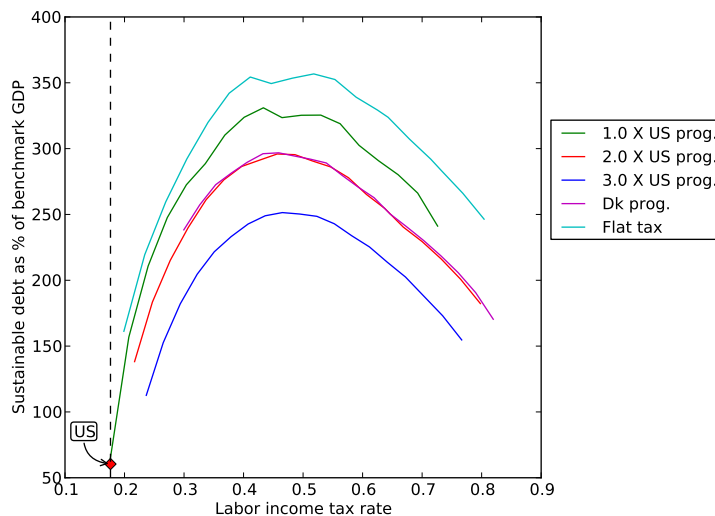


Figure 3: Sustainable levels of debt for varying labor tax progressivity (closed economy)

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

In Figure 3 we plot the maximum sustainable debt level as a function of the average tax rate for varying degrees of progressivity. For its current choice of progressivity, the US can sustain a debt burden of about 3.3 times its benchmark GDP. 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%.

In Figure 2 one may notice that 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. With more heterogeneity in the fixed costs (but also higher computational cost) it is possible to get smoother Laffer curves. In Figure 4 we plot Laffer curves from a model that do not have the extensive margin for women but is otherwise similar and has been calibrated to match the same characteristics of the US economy. The Laffer curve without extensive margin are smooth. Removing the extensive margin, however, shifts the Laffer curves up and to the right.

### ***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 of 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

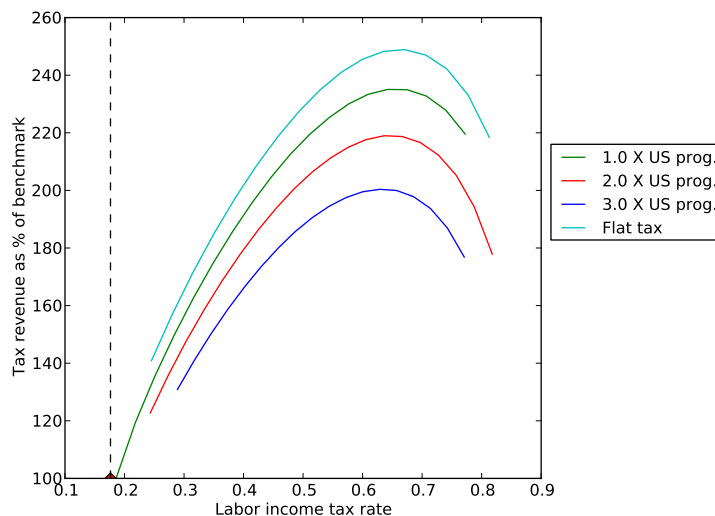


Figure 4: The impact of progressivity on the laffer curve in a model without extensive margin, when new revenues are used for paying interest on debt (closed economy)

includes the revenue from the social security taxes<sup>13</sup>. 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.

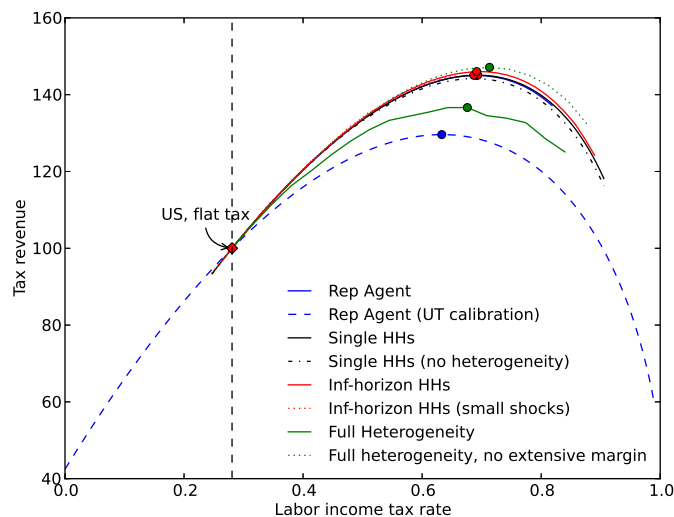


Figure 5: Laffer curves from different models

<sup>13</sup>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.

In figure 5 we graph 7 Laffer curves. The green line is the Laffer curve from our original model. The green dotted line is from the full model without the extensive margin and human capital accumulation for women. The blue dashed line and the blue solid line are from the representative agent model of Trabandt and Uhlig (2011). In the solid line we use their code but parameter values similar to those used in our study. In particular we set the parameter  $\eta$  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 solid line is the Laffer curve from an infinite horizon model with heterogeneity in permanent abilities and idiosyncratic productivity shocks. The black solid line is from a single-household, life-cycle model with heterogeneity in permanent abilities and idiosyncratic productivity shocks, whereas the black dotted line is from a life-cycle model where age is the only form of heterogeneity.

The Laffer curves with  $\eta = 1/0.6$  seem to fall in 2 groups. All the curves are relatively close together, except for the curve from the model with extensive margin and human capital accumulation. It appears that simply increasing the heterogeneity of the income distribution in a life-cycle or infinite horizon model has a relatively modest impact on the Laffer curve. Adding extensive margin labor supply and human capital accumulation for women, however, lowers the curve and moves the locus of the peak to the left.

It is as expected that the full heterogeneity model with extensive margin labor supply and human capital accumulation for women is lower than the other curves. Adding the extensive margin can only increase the negative response of labor supply to taxes. When women outside of the labor force also loose out on human capital accumulation this reduces their future earnings ability and further lowers the Laffer curve.

As one would expect, the  $\eta$  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. 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.

#### 6.4 Interaction of Tax Progressivity and Household Heterogeneity

Below we plot the peak of the Laffer curve as a function of tax progressivity in five different models; our benchmark heterogeneous agents model, a representative agent model, a life-cycle model where age is the only form of heterogeneity, a life-cycle model with heterogeneity in permanent abilities and idiosyncratic productivity shocks, and an infinite horizon model with heterogeneity in permanent abilities and shocks. The impact of progressivity on the Laffer curve is remarkably similar in four of these models, although the variance of income and wages is very different. In the benchmark heterogeneous agent model, the impact of progressivity is smaller.

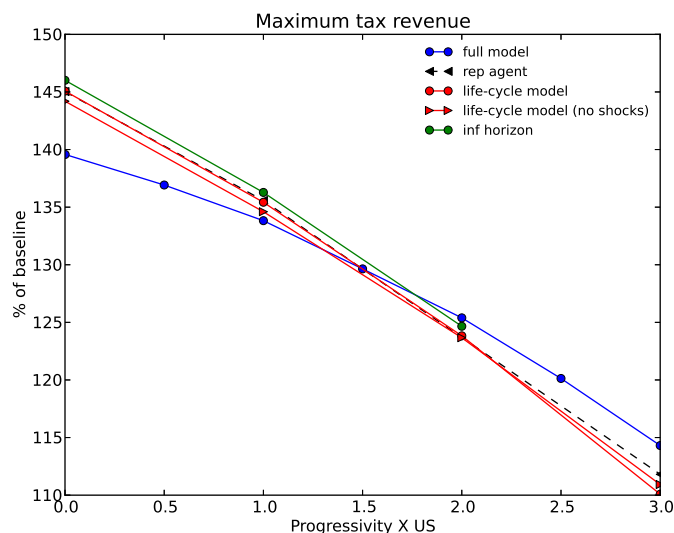


Figure 6: Laffer curves from different models



## 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 (especially its, progressivity, but also its structure -labor, 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, 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 a German Tax System?*

In a first step we now implement a German tax and transfer system in our U.S. calibrated economy. Relative to U.S. fiscal policy, the German tax system is characterized by (details TBC).

### *7.2 The Impact of the Wage Distribution*

Now we re-calibrate the entire model to German data and display the impact of the size of wage dispersion on the Laffer curve. We proceed in two steps (may!). First, we insert a "German" wage process into the model with German tax system, but maintain all other parameters at their U.S.-calibrated level. Second, we fully re-calibrate the entire economy to German data.

## 8 Conclusion

In this paper we characterized the Laffer curve for X countries, and argued that the their shape and peak is crucially determined by the degree of tax progressivity in these countries.

## 9 Appendix

### *9.1 Balanced growth with labor participation margin*

As is well-known<sup>14</sup>, 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 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

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<sup>14</sup>See King, Plosser, and Rebelo (2002) for details

separate additive term which can be ignored:

$$\begin{aligned}
E_t \sum_{j=J}^{100-J} \beta^j [\log(c_{t,j}) + v(n_j) - F1_{[n_j>0]}] &= E_t \sum_{j=J}^{100-J} \beta^j [\log(c_{t,j}/Z_t) + v(n_j) - F1_{[n_j>0]} + \log(Z_t)] \\
&= E_t \sum_{j=J}^{100-J} \beta^j [\log(c_j^z) + v(n_j) - F1_{[n_j>0]}] + E_t \sum_{t=j} \beta^t \log(Z_t)
\end{aligned}$$

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:

$$\begin{aligned}
E_t \sum_{j=J}^{100-J} \beta^j \left[ \frac{1}{1-\nu} c_{t,j}^{1-\nu} v(n_j) - F1_{[n_j>0]} \right] &= \\
E_t \sum_{j=J}^{100-J} \tilde{\beta}^j \left[ \frac{1}{1-\nu} (c_j^z)^{1-\nu} v(n_j) \right] - E_t \sum_{j=J}^{100-J} \beta^j F1_{[n_j>0]}
\end{aligned}$$

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

## 9.2 Recursive formulation of the household problem

Households of age  $J$  in period  $t$  maximize

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

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

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

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

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

$W_{t,j}^{L,m}$  and  $W_{t,j}^{L,w}$  are the labor incomes of the two household members:

$$W_{t,j}^{L,i} = \frac{n_{t,j}^i w_t e^{a_i + \gamma_{0i} + \gamma_{1i} e_{t,j}^i + \gamma_{2i} (e_{t,j}^i)^2 + \gamma_{3i} (e_{t,j}^i)^3 + u_{t,j}^i}}{1 + \tilde{\tau}_{ss}}, \quad i = m, w$$

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

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  $c_j^z = c_{t,j}/Z_t$  and  $k_j^z = k_{t,j}/Z_t$  and conjecture that they do not depend on the calendar time  $t$  either. This allows us to rewrite the budget constraints as:

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

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

$$1 - \frac{1 - \tau(y_2)}{1 - \tau(y_1)} = 1 - \left(\frac{y_2}{y_1}\right)^{-\theta_1} \quad (10)$$

and therefore independent of the scaling parameter  $\theta_0$ . Thus by construction one can raise average taxes by lowering  $\theta_0$  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<sup>15</sup> is uniquely determined by the parameter  $\theta_1$ . Heathcote, Storesletten, and Violante (2012) estimate the parameter  $\theta_1 = 0.18$  for all households. Above we let  $\theta_1$  vary by family type.

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<sup>15</sup>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.

#### 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) or years of labor market experience (women),  $e$ , as well as dummies for the year of observation,  $D$ :

$$\log(w_{it}) = \phi_i(\text{constant} + D'_t \zeta + \gamma_1 x_i t + \gamma_2 x_i t^2 + \gamma_3 x_i t^3 + u_i t) \quad (11)$$

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 on various demographic characteristics,  $Z$ :

$$\Phi(\text{participation}) = \Phi(Z_i t' \xi + v_i t) \quad (12)$$

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,  $\sigma_\iota$ ,  $\rho_\iota$  and  $\sigma_{\alpha_\iota}$  we obtain the residuals  $u_i t$  and use them to estimate the below equation by fixed effects estimation:

$$u_{it} = \alpha_i + \rho u_{it-1} + \epsilon_{it} \quad (13)$$

The parameters can be found in Table 2.

## 9.5 Tables and Figures

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

Country	Married 0C		Married 1C		Married 2C		Single 0C	
	$\theta_0$	$\theta_1$	$\theta_0$	$\theta_1$	$\theta_0$	$\theta_1$	$\theta_0$	$\theta_1$
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

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