How Does Tax-Progressivity Affect OECD Laffer Curves?*

Hans A. Holter[†] Dirk Krueger[‡] Serhiy Stepanchuk[§]

July 2013

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 X 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... (has to be updated as we go along).

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

JEL: E62, H20, H60

*We thank Per Krusell for helpful discussions and comments. Hans A. Holter is grateful for financial support from Handelsbanken Research Foundations.

[†]Uppsala University and UCFS

[‡]University of Pennsylvania, CEPR and NBER

[§]Magyar Nemzeti Bank

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, 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 X 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.[1]

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

[1]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 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). 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 the next section we describe our quantitative OLG economy with heterogeneous households and define a competitive equilibrium. Section 3 is devoted to the calibration and country-specific estimation of the model parameters, and Section 4 describes the computational Laffer curve thought experiments we implement in this paper. The main quantitative results of the paper are presented in section 5, whereas Section 6 contains a sensitivity analysis of the results with respect to crucial modeling and parameter choices. We conclude in section 7. 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 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 the representative agent model employed by Trabandt and Uhlig (2011).

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[2]. For convenience, we will set $Z_0 = 1$ and choose K_0 so that $Y_0 = 1$. This implies that $Y_t = Z_t$.

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

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 cometitive equilibrium, the factor prices will be equal to their marginal products:

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

$$r_t = \partial Y_t/\partial K_t - \delta = \alpha Z_t^{1-\alpha}\left(\frac{L_t}{K_t}\right)^{1-\alpha} - \delta = \alpha\left(\frac{L_t}{K_t/Z_t}\right)^{1-\alpha} - \delta \tag{2}$$

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.

Demographics

The economy is populated by J overlapping generations of finitely lived households. We assume that each household is composed of two adults, a husband and a wife, and one child.[3] We assume that within the same household, the husband and the wife have the same age. They start life at age 20 and enter retirement at age 65.

Let j denote the household's age. Retired households face an age-dependent

[3] In our model, children only influence the taxes that the household needs to pay.

probability of dying, $\pi(j)$, and die for certain at age 100.[4]. 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, 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 the husband always works some positive hours during his working age. However, a wife can either work or stay at home. They jointly decide on how many hours to work, how much to consume, and how much to save. If the wife participates in the labor market, she accumulates one year of labor market experience. Since the husband always works, he accumulates an additional year of working experience every period. Retired households make no labor 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 to denote the per-household bequest.

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

[4]This means that $J = 76$.

this shock is not common to all households). Thus, the wage of an individual i is given by:

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

$$u_i' = \rho_\iota u_i + \epsilon_i, \quad \epsilon_i \sim N(0, \sigma_\iota^2) \tag{4}$$

$\gamma_{0\iota}$ 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.

Preferences

The momentary utility function, U, 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:

$$U(c, n^m, n^w) = \log(c) - \chi \frac{(n^m)^{1+\eta}}{1+\eta} - \chi \frac{(n^w)^{1+\eta}}{1+\eta} - F \cdot \mathbb{1}_{[n^w > 0]} \tag{5}$$

where F is here 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 $n > 0$.

King, Plosser, and Rebelo (2002) show that in a setup with no participation decision, such 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.

Using the results in Trabandt and Uhlig (2011), it also follows that these are the only preferences consistent with both long-run balanced growth and with constant Frisch elasticity of labor supply, which in this case is equal to $1/\eta$.

Government

We assume that there is some outstanding government debt, and that government debt to output ratio, $B_Y = B_t/Y_t$, does not change over time. The government 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. We assume that a fraction $(1-\vartheta)$ of the government revenues are spent on pure public consumption goods. 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_0 govern the level and the progressivity of the tax code, respectively.[5]. Heathcote, Storesletten, and Violante (2012) argue that this fits the U.S. data well. In addition, the government collects social security contributions to finance the retirement benefits and the transfers to people who do not participate in the labor market.

Denoting the fraction of women[6] that work 0 hours by ζ_t, the government budget constraint takes the following form:

$$2\left(g_t/Y_t\right)\left(45+\sum_{j\geq 65}\Omega_j\right)+45\left(T_t/Y_t\right)\zeta_t=\left(R_t/Y_t\right)-\left(G_t/Y_t\right)+\left(\mu-r\right)\left(B_t/Y_t\right),$$
$$2\left(\Psi_t/Y_t\right)\left(\sum_{j\geq 65}\Omega_j\right)=\left(R_t^{ss}/Y_t\right).$$

where R_t are the government's revenues from the labor, capital and consumption taxes, R_t^{ss} are the government's revenues from the social security taxes, Ψ_t are the pension payments and T_t are the unemployment benefits.

In a BGP with constant tax rates, the ratio of government revenues to output will also remain constant. Combined with the above government budget constraints, this

[5]A further discussion of the properties of this tax function is provided in the appendix
[6]Recall that we assume that men always work.

implies that in the steady state equilibrium g_t, Ψ_t and T_t must remain proportional to output. We define the following ratios:

$$g^z = g_t/Z_t = g_t/Y_t, \quad \Psi^z = \Psi_t/Z_t = \Psi_t/Y_t, \quad T^z = T_t/Z_t = T_t/Y_t.$$

Since in the BGP output is growing at the same rate as Z_t, g^z, Ψ^z and T^z will also be constant over time.

Recursive Formulation of the Household Problem

At any given time, a household is characterized by $(k, e^m, e^w, u^m, u^w, a^m, a^w, j)$, 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, j is the household's age. Recall that we assumed that the husband's experience is always equal to his age, $e^m = j$.

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 the households recursively:

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

s.t.:

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

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

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

$$
(e^m)' = e^m + 1,
$$

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

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

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

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, τ_{ss} and $\tilde{\tau}_{ss}$ are the social security contributions paid by the employee and by the employer.

Recursive Competitive Equilibrium

We call an equilibrium of the growth adjusted economy a stationary equilibrium.[7] Let $\Phi(k, e^m, e^w, u^m, u^w, a^m, a^w, j)$ be the measure of households with the corresponding characteristics. We now define such a stationary recursive competitive equilibrium as follows:

Definition:

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

1. The value function $V(k, e^m, e^w, u^m, u^w, a^m, a^w, j)$ and policy functions, $c^z(k, e^m, e^w, u^m, u^w, a^m, a^w, j)$, $k^z(k, e^m, e^w, u^m, u^w, a^m, a^w, j)$, $n^m(k, e^m, e^w, u^m, u^w, a^m, a^w, j)$ and $n^w(k, e^m, e^w, u^m, u^w, a^m, a^w, j)$, solve the consumers' optimization problem given the factor prices and initial conditions.

2. Markets clear:

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

$$L = \int \left(n^m e^{a^m + \gamma_1 e^m + \gamma_2 (e^m)^2 + \gamma_3 (e^m)^3 + u^m} + n^w e^{a^w + \gamma_1 e^w + \gamma_2 (e^w)^2 + \gamma_3 (e^w)^3 + u^w} \right) d\Phi$$

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

3. The factor prices satisfy:

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

4. The government budget balances:

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

5. The social security system balance:

$$\Psi^z \int_{j \geq 65} d\Phi = \frac{\tilde{\tau}_{ss} + \tau_{ss}}{1 + \tilde{\tau}_{ss}} \int_{j<65} (n^m w^{mz}(a^m, e^m, u^m) + n^w w^{wz}(a^w, e^w, u^w)) d\Phi$$

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

$$\Gamma^z \int \omega(j) d\Phi = \int (1 - \omega(j))\, k^z(.,j) d\Phi$$

3 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 1. The 4 parameters in Table 2 below are, however, calibrated using an exactly identified simulated method of moments approach.

Preferences

The momentary utility function is given in equation 5. The discount factor, β, the fixed cost of working, F, and the disutility of working more hours χ are among the estimated parameters. The corresponding data moments are the ratio of capital to output, K/Y, taken from the BEA, the female employment rate, taken from the CPS, and hours per person 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. We set $\eta = 0.4$ which is in line with contemporary literature, see for instance Guner, Kaygusuz, and Ventura (2011). Note that η will not be the macro elasticity of labor labor supply with respect to tax rates, see **?**.

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.

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 8 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 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 wages.

Taxes

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[8]. 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:

$$ya = \theta_0 y^{1-\theta_1} \tag{6}$$

We use labor income tax data from the OECD to estimate the parameters θ_0 and θ_1. We use the tax schedule for a family with 2 adults and 1 child. 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

[8]see Appendix 8 for more details.

incomes, 7.65% for both τ_{SS} and $\tilde{\tau}_{SS}$. We follow Trabandt and Uhlig (2011) and set $\tau_k = 36\%$ and $\tau_c = 5\%$.

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 cost of working, which we calibrate to hit the employment rate for women. 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.

To determine the fraction (ϑ) of the government's income, which can be spent on individuals in the model 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.

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 eight data moments in column 3 of Table 2. Let $\Theta = \{\gamma_{0m}, \beta, F, \chi\}$ and let $V(\Theta) = (V_1(\Theta), \ldots, V_4(\Theta))'$ 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:

$$\hat{V} = \min_{\Theta} V(\Theta)'V(\Theta) \tag{7}$$

Table 1: Parameters Calibrated Outside of the Model

Parameter	Value	Description	Target
$1/\eta$	0.4	$U(c, n^m, n^w) = \log(c) - \chi\frac{(n^m)^{1+\eta}}{1+\eta} - \chi\frac{(n^w)^{1+\eta}}{1+\eta} - F \cdot \mathbb{1}_{[n^w>0]}$	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	$u' = \rho_{jg} u + \epsilon$	
ρ_m, ρ_w	0.396, 0.339	$\epsilon \sim N(0, \sigma_{jg}^2)$	
σ_{am}, σ_{aw}	0.338, 0.385	$a_\iota \sim N(0, \sigma_{a_m}^2)$	
θ_0, θ_1	(0.9400, 0.1544)	$ya = \theta_0 y^{1-\theta_1}$	OECD tax data
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
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)

Table 2: Parameters Calibrated Endogenously

Parameter	Value	Description	Moment	Moment Value
γ_{0m}	-1.310	$w_t(a_i, e_i, u_i) = w_t e^{a_i+\gamma_{0w}+\gamma_{1w}e_i+\gamma_{2w}e_i^2+\gamma_{3w}e_i^3+u_i}$	Gender earnings ratio	2.059
β	1.003	Discount factor	K/Y	2.640
F	0.013	$U(c, n^m, n^w) = \log(c) - \chi\frac{(n^m)^{1+\eta}}{1+\eta} -$	Female employment rate	0.687
χ	26.100	$\chi\frac{(n^w)^{1+\eta}}{1+\eta} - F \cdot \mathbb{1}_{[n^w>0]}$	Hours/(Pop. 20-64)	0.268 (1466 h/year)

Table 2 summarizes the estimated parameter values and the data moments. We match all the moments exactly so that $V(\Theta)'V(\Theta) = 0$.

4 Computational Experiments

Wedge based measures of tax-progressivity are common in the literature. We adopt the following tax progressivity wedge, where $\tau(y)$ is the average tax rate: from:

$$PW(y_1, y_2) = 1 - \frac{1 - \tau(y_2)}{1 - \tau(y_1)} \tag{8}$$

This measure always takes a value between 0 and 1 and increases with the increase in the marginal tax rate τ 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. Analogues measures of tax progressivity are used by Guvenen, Kuruscu, and Ozkan (2009) and **?**.

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. **?** 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 θ_1, see Section 8. One can increase the tax level while keeping tax progressivity constant for all levels of y_1 and y_2 just by changing θ_0.

We start by calibrating the model to data from each of the countries that we consider. We then perform the following exercises:

1. We characterize US laffer curves and debt laffer curves (the maximal sustainable debt at a given tax rate) for varying levels of progressivity as defined by 8.

2. We characterize the Laffer curves and debt Laffer curves in a number of countries while holding tax progressivity as defined by equation 8 constant for all levels of y_1 and y_2. The Laffer curves in different countries will be different for 3 reasons. The shape of the tax schedule is different, the distribution of wages and the returns to experience is different, and the social security systems, capital and consumption taxes are different.

3. We study the importance of the wage distribution for the Laffer curve. We do this by introducing a tax system with US progressivity wedges in all countries and characterizing the Laffer curves.

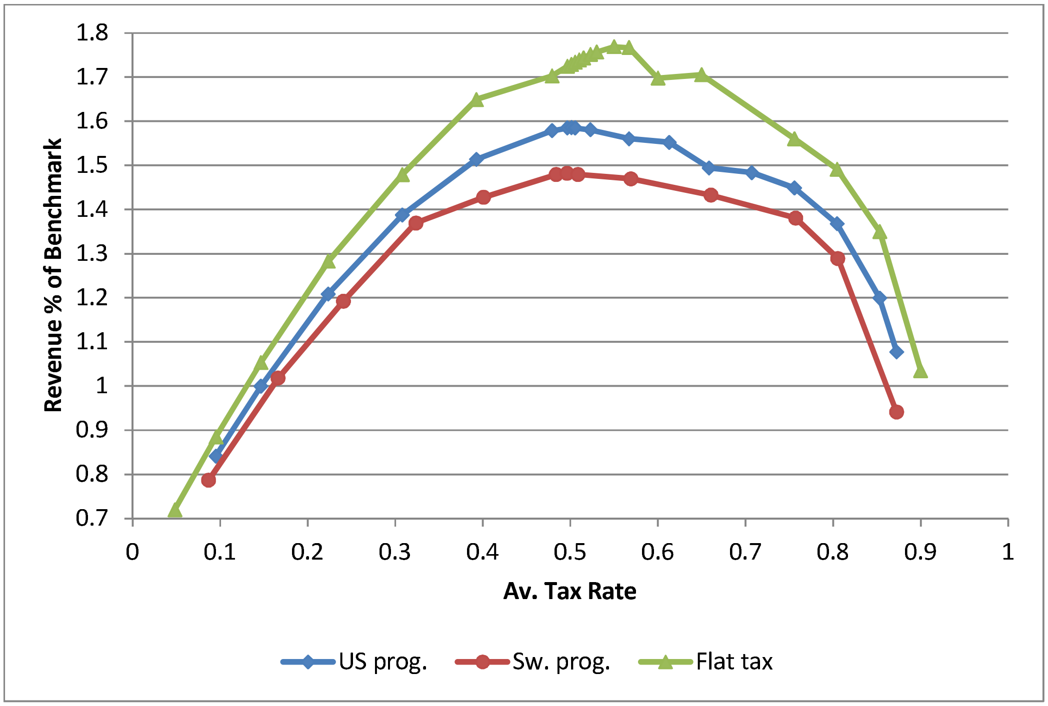
5 Results

In this section we display the main quantitative results of our paper.

5.1 The Effect of Tax Progressivity on the Peak of the Laffer Curve

In Figure 1 we plot Laffer curves for our simulated US economy while varying the progressivity of the tax system. We consider 3 cases; a system with progressivity equal to the current US system (blue line), a system with progressivity equal to the current Swedish system (red line), and a flat tax (green line). We observe that the design of the tax system has considerable impact on the Laffer curve. A less progressive tax system generally generates more tax revenues. The maximal government

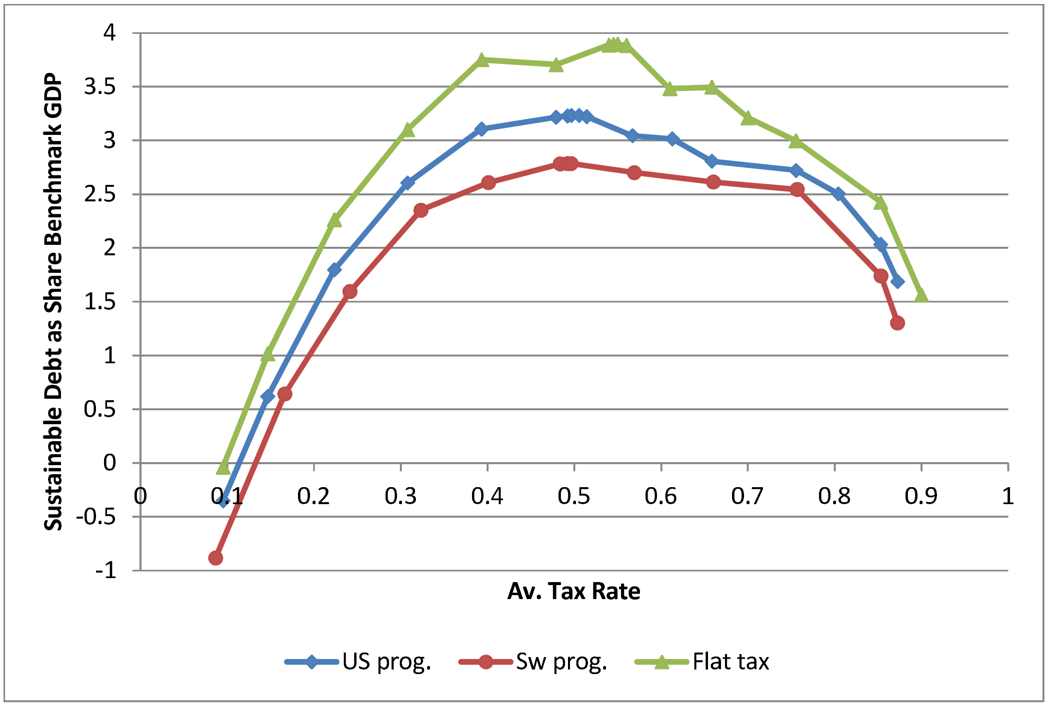
Figure 1: Simulated US Laffer Curves at Different Levels of Progressivity



income that can be generated with a flat tax system is 11.6% higher than the maximal revenues that can be generated when the tax schedule exhibits a progressivity similar to the current US system. A tax schedule with the current US progressivity can again generate 7% more revenue than a tax system with Swedish progressivity.

Figure 2 displays the maximal debt that can be sustained at a given tax rate, while keeping government spending, G, and lump sum transfers, g at their benchmark levels, for different levels of tax-progressivity. The design of the tax system has considerable impact also on the debt Laffer curve. A less progressive tax system generally generates more tax revenues and also keep more people working, reducing the transfers to unemployed. The maximal debt that can be sustained with a flat tax system is 20.5% higher than the maximal debt that can be sustained when the tax schedule exhibits a progressivity similar to the current US system. A tax schedule with the current US progressivity can again sustain 16.3% more revenue than a tax system with Swedish progressivity.

Figure 2: Simulated US Debt Laffer Curves at Different Levels of Progressivity



5.2 Inspecting the Mechanisms

5.3 Laffer Curves for X Countries

6 Sensitivity Analysis

To compare our results to the ones obtained in Trabandt and Uhlig (2011), we consider a model that is identical to theirs. To that end, we make 2 changes to our previous setup. First, we assume that households live forever. Their utility function is given by:

$$E_0 \sum_{t=t_0}^{\infty} \beta^{t-t_0}(c,n) \tag{9}$$

where $U(c,n)$ is the same as in (5), with $F = 0$. Second, we assume that, instead of accumulating experience, workers accumulate human capital according to the following human capital production function:

$$h_t = H(h_t, k_t) = (Aq_t n_t + B(1 - q_t)n_t)^{\omega} h_{t-1}^{1-\omega} + (1 - \delta_h)h_{t-1} \tag{10}$$

where, as before, n_t is non-leisure time. However now on top of deciding how much time to devote to leisure vs work, the worker also has to decide what fraction of his non-leisure time to spent actually working, q_t, with the remainder being devoted to on-job learning. The total aggregate amount of labor efficiency units becomes:

$$L = \int nhqd\Phi \tag{11}$$

Recursively, the household problem can be formulated as:

$$\begin{aligned} V(k, h, u) &= \max_{c,n,k',q} \log(c) - \chi \frac{n^{1+\eta}}{1+\eta} + \beta E_{u'}\big[V(k', h', u')\big] \\ \text{s.t.:} \quad c(1 + \tau_c) + k'(1 + \mu) &= k\,(1 + r(1 - \tau_k)) + nw(h)(1 - \tau_l(w(h)n)) + g, \\ h' = H(h, n), \quad n &\in [0, 1], \quad q \in [0, 1], \quad x \geq 0, \quad c > 0 \end{aligned} \tag{12}$$

7 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.

8 Appendix

Balanced growth with labor participation margin

As is well-known[9], 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 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

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

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).

Recursive formulation of the household problem

Households of age J in period t maximize

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

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):

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

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

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

which depend on the individual's fixed type a_i, experience $e^i_{t,j}$ (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:

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

Substituting $c_{t,j} = c^z_j Z_t$ 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.

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

$$1-\frac{1-\tau(y_2)}{1-\tau(y_1)} = 1-\left(\frac{y_2}{y_1}\right)^{-\theta_1} \tag{13}$$

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[10] is uniquely determined by the parameter θ_1.

In terms of calibration one would try to choose θ_1 to match a measure of tax progressivity: any observation on a tax wedge between any two income levels is sufficient to uniquely pin down θ_1 from equation (13). The scale parameter θ_0 is then chosen to assure government budget or to achieve a target fraction of tax revenue to GDP. Heathcote et al. (2012) estimate the parameter $\theta_1 = 0.18$.

[10]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.

Estimation of Returns to Experience and Shock Processes From the PSID

We take the log of equation 3 and estimate a log(wage) equation using data from the non-poverty sample of the PSID 1968-1997. Equation 4 is estimated using the residuals from 3.

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:

$$log(w_{it}) = \phi_i(constant + D_t'\zeta + \gamma_1 x_i t + \gamma_2 x_i t^2 + \gamma_3 x_i t^3 + u_i t) \tag{14}$$

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:

$$\Phi(participation) = \Phi(Z_i t'\xi + \upsilon_i t) \tag{15}$$

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 σ_{α_ι} we obtain the residuals $u_i t$ and use them to estimate the below equation by fixed effects estimation:

$$u_{it} = \alpha_i + \rho u_{it-1} + \epsilon_{it} \tag{16}$$

The parameters can be found in Table 1.

Tables and Figures

Number of children	Percent	Tax progressivity measure θ_1
0	50.15	0.1206
1	20.76	0.1434
2	18.67	0.1678
3	7.46	0.1846
4	2.11	0.1976
5	0.56	0.1206
6	0.18	0.1206
7	0.07	0.1206
8	0.03	0.1206
9+	0.02	0.1206

Table 3: Distribution of households (with a head between 20 and 64 years of age) by the number of children, 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 4: 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

References

Aiyagari, R., 1994, Uninsured Risk and Aggregate Saving, *Quarterly Journal of Economics* 109, 659–684.

Benabou, R, 2002, Tax and Education Policy in a Heterogeneous Agent Economy: What Levels of Redistribution Maximize Growth and Efficiency?, *Econometrica* 70, 481–517.

Conesa, Juan Carlos, Sagiri Kitao, and Dirk Krueger, 2008, Taxing Capital? Not a Bad Idea After All!, *American Economic Review* 99, 25–48.

Feve, P., J. Matheron, and J.G. Sahuc, 2013, The Laffer Curve in an Incomplete-Market Economy, Working paper.

Guner, Nezih, Remzi Kaygusuz, and Gustavo Ventura, 2011, Taxation and Household Labor Supply, *Review of Economic Studies, forthcoming.*

Guvenen, Fatih, Burhanettin Kuruscu, and Serdar Ozkan, 2009, Taxation of Human Capital and Wage Inequality: A Cross-Country Analysis, Working Paper 15526 National Bureau of Economic Research.

Heathcote, J., S. Storesletten, and G. Violante, 2012, Redistribution in a Partial Insurance Economy, Working paper.

Heckman, James, 1976, The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models, *The Annals of Economic and Social Measurement* 5, 475–492.

Heckman, James, 1979, Sample Selection Bias as a Specification Error, *Econometrica* 47, 153–162.

Keane, Michael P., 2011, Labor Supply and Taxes: A Survey, *Journal of Economic Literature* 49, 961–1045.

King, R.G., C.I. Plosser, and S.T. Rebelo, 2002, Production, growth and business cycles: Technical appendix, *Computational Economics* 20, 87–116.

Prescott, Edward C., 2004, Why do Americans Work so Much More Than Europeans, *Federal Reserve Bank of Minneapolis Quarterly Review* 28, 2–13.

Trabandt, Mathias, and Harald Uhlig, 2011, The Laffer Curve Revisited, *Journal of Monetary Economics* 58, 305–327.