On the Optimal Progressivity of the Income Tax Code

Juan Carlos Conesa Dirk Krueger

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Juan Carlos Conesa   Dirk Krueger
Universitat de Barcelona and CREB   Stanford University

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Abstract

This paper computes the optimal progressivity of the income tax code in a dynamic general equilibrium model with household heterogeneity in which uninsurable labor productivity risk gives rise to a nontrivial income and wealth distribution. A progressive tax system serves as a partial substitute for missing insurance markets and enhances an equal distribution of economic welfare. These beneficial effects of a progressive tax system have to be traded off against the efficiency loss arising from distorting endogenous labor supply and capital accumulation decisions. A determination of the optimal progressivity of the income tax code therefore calls for a quantitative exploration.

Using a utilitarian steady state social welfare criterion we find that the optimal US income tax is well approximated by a flat tax rate of 19.5% and a fixed deduction of about $3,700. The steady state welfare gains from a fundamental tax reform towards this tax system are equivalent to 0.4% higher consumption in each state of the world. An explicit computation of the transition path induced by a reform of the current towards the optimal tax system indicates, however, that a majority of the population currently alive would suffer welfare losses, calling into question the political feasibility of such fundamental income tax reform.

Keywords: Progressive Taxation, Optimal Taxation, Social Insurance, Transition
J.E.L. classification codes: E62, H21, H24

1. Introduction

Progressive income taxes play two potentially beneficial roles in affecting consumption, saving and labor supply allocations across households and over time. First, they help to enhance a more equal distribution of income, and therefore, possibly, wealth, consumption and welfare. Second, in the absence of formal or informal private insurance markets against idiosyncratic uncertainty progressive taxes provide a partial substitute for these missing markets and therefore may lead to less volatile household consumption over time.

However, progressive taxation has the undesirable effect that it distorts incentives for labor supply and saving (capital accumulation) decisions of private households and firms. The policy maker therefore faces nontrivial trade-offs when designing the income tax code.

On the theoretical side, several papers characterize the optimal tax system when two of these effects are present. The seminal paper by Mirrlees (1971) focuses on the traditional tension between equity and labor supply efficiency, whereas Mirrlees (1974) and Varian (1980) investigate the trade-offs between labor supply efficiency and social insurance stemming from progressive taxation. Aiyagari (1995) shows that, in the presence of uninsurable idiosyncratic uncertainty the zero capital tax result by Judd (1985) and Chamley (1986), derived from the desired efficiency of capital accumulation, is overturned in favor of positive capital taxation. Aiyagari's result is due to the fact that positive capital taxes cure overaccumulation of capital in the light of uninsurable idiosyncratic income shocks, rather than influence the risk allocation directly. Golosov et. al. (2001) present a model with idiosyncratic income shocks and private information where positive capital taxes, despite distorting the capital accumulation decision, are optimal because they improve the allocation of income risk by alleviating the effects that the informational frictions have on consumption allocations.

Common to these papers is that, in order to insure analytical tractability, they focus on a particular trade-off and derive the qualitative implications for the optimal tax code. In contrast, in this paper we *quantitatively* characterize the optimal progressivity of the income tax code in an economic environment where *all three* effects of progressive taxes (the insurance, equity and efficiency effects) are present simultaneously.

In our overlapping generations economy agents are born with different innate earnings ability and face idiosyncratic, serially correlated income shocks as in Huggett (1993) and Aiyagari (1994). These income shocks are uninsurable by assumption; the only asset that is being traded for self-insurance purposes is a one-period risk-free bond which cannot be shortened. In each period of their finite lives agents make a labor-leisure and a consumption-saving decision, which is affected by the tax code. The government has to finance a fixed exogenous amount of government spending via proportional consumption taxes, taken as given in the analysis, and income taxes, which are the subject of our analysis. We restrict the income tax code to lie in a particular class of functional forms. This functional form, which has its theoretical foundation in the equal sacrifice approach (see Berliant and Gouveia (1993)), has two appealing features. First, it provides a close approximation to the actual US income tax code, as demonstrated by Gouveia and Strauss (1994). Second, it provides a flexible functional form, nesting a proportional tax code, a wide variety of progressive tax codes and a variety of regressive tax codes such as a poll tax, with few parameters, which makes numerical optimization over the income tax code feasible.

The social welfare criterion we use in order to evaluate different income tax codes is steady

state ex-ante expected utility of a newborn agent, before it is known with which ability level (and thus earnings potential) that agent will be born (i.e. looking upon her future life with the Rawlsian veil of ignorance). Thus, progressive taxes play a positive role in achieving a more equal distribution of income and welfare (or in other words, they provide insurance against being born as a low-ability type). They also provide a partial substitute for missing insurance markets against idiosyncratic income shocks during a person's life. On the other hand, labor-leisure and consumption-saving decisions are distorted by the potential presence of tax progressivity.

Our first main quantitative result is that the optimal income tax code is well approximated by a proportional income tax with a constant marginal tax rate of 19.5% and a fixed deduction of roughly $3,700. Under such a tax code aggregate labor supply is 1.8% higher and aggregate output is 2.7% higher than in the benchmark tax system, calibrated to roughly match the US system. Households with annual income below around $6,100 and above $38,600 would pay lower total income taxes as compared to the benchmark, whereas the middle class, the households with incomes between $6,100 and $38,600 face a substantially higher income tax bill. The implied steady state welfare gains from such a tax reform are in the order of magnitude equivalent to a uniform 0.4% increase in consumption across *all* agents and *all* states of the world.

The intuition for this result, which supports voices arguing for flat tax reform such as Hall and Rabushka (1995), is that lower marginal tax rates for high-income people increase labor supply and savings incentives, whereas the desired amount of redistribution and insurance is accomplished by the fixed deduction. That the desire for redistribution and insurance, nevertheless, is quantitatively important is reflected in our finding that a pure flat tax, without deduction, leads to a *reduction* in welfare, compared to the US. benchmark, even though aggregate output increases by 6.0% compared to the benchmark.

These results seem to suggest that sizeable welfare benefits are forgone by passing on a fundamental tax reform. Our second main quantitative result, based on an explicit computation of the transition path induced by such a reform, questions this assessment. In particular, we find that, despite the large steady state welfare gains, a majority of the agents currently alive would face negative welfare consequences from such a reform, putting into question the political feasibility of a flat tax reform of the type suggested by the first part of our analysis. As our steady state findings suggest, households located around the median of the labor earnings and wealth distribution tend to suffer most from the reform; our analysis suggests that the middle class may be the biggest opponent to the proposed tax reform.

Several other studies attempt to quantify the trade-offs involved with reforming the (income) tax code in models with consumer heterogeneity. Castañeda et al. (1998) and Ventura (1999) use a model similar to ours in order to compare in detail the steady state macroeconomic and distributional implications of the current progressive tax system with those of a proportional (flat) tax system. We add to this literature the normative dimension of discussing *optimal* income taxation (with the implied cost of having to take a stand on a particular social welfare functional), as well as an explicit consideration of transitional dynamics induced by a potential tax reform. Domeij and Heathcote (2001) investigate the allocational and welfare effects of abolishing capital and income taxes, taking full account of the transition. but do not optimize over the possible set of policies. Saez (2001) investigates the optimal

progressivity of capital income taxes; in particular he focuses on the tax treatment of the top tail of the wealth distribution. In order to derive analytical results labor income is exogenous, deterministic and not taxed in his model, so that the labor supply and insurance aspects of progressive taxation are absent by construction. Finally, Caucutt et al. (2001) and Benabou (2002) study the effects of the progressivity of the tax code on human capital accumulation and economic growth. Their analysis devotes more detail to endogenizing economic growth than our study, but allows only limited cross-sectional heterogeneity and intertemporal trade; by stressing distributional and risk allocation aspects we view our analysis as complementary to theirs.

The paper is organized as follows: in Section 2 we describe the economic environment and define equilibrium. Section 3 contains a discussion of the functional forms and the parameterization employed in the quantitative analysis. In Section 4 we describe our computational experiments and in Section 5 we summarize our results concerning the optimal tax system and steady state welfare consequences of a tax reform. Section 6 is devoted to a discussion of the allocative and welfare consequences of a transition from the actual tax system to the optimal system derived in Section 5. Conclusions can be found in Section 7.

2. The Economic Environment

2.1. Demographics

Time is discrete and the economy is populated by J overlapping generations. In each period a continuum of new agents is born, whose mass grows at a constant rate n. Each agent faces a positive probability of death in every period. Let $\psi_j = prob$(alive at $j+1$|alive at j) denote the conditional survival probability from age j to age $j+1$. At age J agents die with probability one, i.e. $\psi_J = 0$. Therefore, even in the absence of altruistic bequest motives, in our economy a fraction of the population leaves accidental bequests. These are denoted by Tr_t and distributed as lump-sum transfers uniformly across agents currently alive. At a certain age j_r agents retire and receive social security payments SS_t at an exogenously specified replacement rate b_t of current average wages. Social security payments are financed by proportional labor income taxes $\tau_{ss,t}$.

2.2. Endowments and Preferences

Individuals are endowed with one unit of productive time in each period of their life and they enter the economy with no assets. Agents can spend their time supplying labor to a competitive labor market or consuming leisure. Individuals are heterogeneous along three dimensions that affect their labor productivity and hence their wage.

First, agents of different ages differ in their average, age-specific labor productivity ε_j. For agents older than j_r (retired agents) we assume $\varepsilon_j = 0$. Furthermore, individuals are born with different abilities α_i which, in addition to age, determine their average deterministic labor productivity. We assume that agents are born as one of M possible ability types $i \in \mathbf{I}$, and that this ability does not change over an agents' lifetime,[1] so that agents, after

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[1] Ability in our model stands in for innate ability as well as for education and other characteristics of an individual that are developed before entry in the labor market, affect a persons' wage and do not change over

the realization of their ability, differ in their current and future earnings potential. The probability of being born with ability α_i is denoted by $p_i > 0$. This feature of the model, together with a social welfare function that values equity, gives a welfare-enhancing role to redistributive fiscal policies.

Finally, workers of same age and ability face idiosyncratic uncertainty with respect to their individual labor productivity. Let by $\eta_t \in \mathbf{E}$ denote a generic realization of this idiosyncratic labor productivity uncertainty at period t. The stochastic process for labor productivity status is identical and independent across agents and follows a finite-state Markov process with stationary transitions over time, i.e.

$$Q_t(\eta, E) = Prob(\eta_{t+1} \in E | \eta_t = \eta) = Q(\eta, E). \tag{1}$$

We assume that there is a unique invariant measure associated with Q, which we denote by Π. All individuals start their life with average stochastic productivity $\bar{\eta} = \sum_{\eta} \eta \Pi(\eta)$, where $\bar{\eta} \in \mathbf{E}$. Different realizations of the stochastic process then give rise to cross-sectional productivity, income and wealth distributions that become more dispersed as a cohort ages. In the absence of explicit insurance markets for labor productivity risk a progressive tax system may be an effective tool to share this idiosyncratic risk across agents.

At any given time individuals are characterized by (a_t, η_t, i, j), where a_t are asset holdings (of one period, risk-free bonds), η_t is stochastic labor productivity status at date t, i is ability type and j is age. An agent of type (a_t, η_t, i, j) deciding to work ℓ_j hours commands pre-tax labor income $\varepsilon_j \alpha_i \eta_t \ell_j w_t$, where w_t is the wage per efficiency unit of labor. Let by $\Phi_t(a_t, \eta_t, i, j)$ denote the measure of agents of type (a_t, η_t, i, j) at date t.

Preferences over consumption and leisure $\{c_j, (1-\ell_j)\}_{j=1}^{J}$ are assumed to be representable by a standard time-separable utility function of the form

$$E \left\{ \sum_{j=1}^{J} \beta^{j-1} \frac{\left(c_j^{\gamma}(1-\ell_j)^{1-\gamma}\right)^{1-\sigma}}{1-\sigma} \right\}, \tag{2}$$

where β is the time discount factor, γ is a share parameter measuring the importance of consumption relative to leisure, and σ is the coefficient of relative risk aversion. Expectations are taken with respect to the stochastic processes governing idiosyncratic labor productivity and the time of death.

2.3. Technology

We assume that the aggregate technology can be represented by a standard Cobb-Douglas production function. The aggregate resource constraint is given by

$$C_t + K_{t+1} - (1-\delta)K_t + G_t \leq K_t^{\alpha} \left(A_t N_t\right)^{1-\alpha} \tag{3}$$

where K_t, C_t and N_t represent the aggregate capital stock, aggregate consumption and aggregate labor input (measured in efficiency units) in period t, and α denotes the capital share.

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a persons' life cycle.

The term $A_t = (1 + g)^{t-1} A_1$ captures labor augmenting technological progress. The depreciation rate for physical capital is denoted by δ. As standard with a constant returns to scale technology and perfect competition without loss of generality we assume the existence of a representative firm operating this technology.

2.4. Government Policy

The government faces a sequence of exogenously given government consumption $\{G_t\}_{t=1}^{\infty}$ and has two fiscal instruments to finance this expenditure. First the government can levy a proportional tax $\tau_{c,t}$ on consumption expenditures, which we take as exogenously given in our analysis. Furthermore it can tax each individual's income, $y_t = (1 - \tau_{ss,t})w_t\alpha_i\varepsilon_j\eta\ell_t + r_t(a_t + Tr_t)$, where w_t and r_t denote the wage per efficiency unit of labor and the risk free interest rate, respectively.[2] We impose the following restrictions on income taxes. First, tax rates cannot be personalized as we are assuming anonymity of the tax code. Second, the government cannot condition tax rates on the source of income, i.e. cannot tax labor and capital income at different rates.[3] Apart from these restrictions, however, income taxes to be paid can be made an arbitrary function of individual income in a given period. We denote the tax code by $T(\cdot)$, where $T(y)$ is the total income tax liability if pre-tax income equals y.

When studying the optimal progressivity of the income tax code, the problem of the government then consists of choosing the optimal tax function $T(\cdot)$, subject to the constraint that this function can only depend on individual income, keeping fixed the stream of government expenditures and the consumption tax rate.

2.5. Market Structure

We assume that workers cannot insure against idiosyncratic labor income uncertainty by trading explicit insurance contracts. Also annuity markets insuring idiosyncratic mortality risk are assumed to be missing. However, agents trade one-period risk free bonds to self-insure against the risk of low labor productivity in the future. The possibility of self-insurance is limited, however, by the assumed inability of agents to sell the bond short; that is, we impose a stringent borrowing constraint upon all agents. In the presence of survival uncertainty, this feature of the model prevents agents from dying in debt with positive probability.[4]

2.6. Definition of Competitive Equilibrium

In this section we will define a competitive equilibrium and a balanced growth path. Individual state variables are individual asset holdings a, individual labor productivity status η, individual ability type i and age j. The aggregate state of the economy at time t is completely

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[2] After retirement, taxable income equals $y_t = SS_t + r_t(a_t + Tr_t)$.

[3] For a study that discusses the effects of changing the mix of capital and labor income taxes, see Domeij and Heathcote (2001).

[4] If agents were allowed to borrow up to a limit, it may be optimal for an agent with a low survival probability to borrow up to the limit, since with high probability she would not have to pay back this debt back. Clearly, such strategic behavior could be avoided if lenders could provide loans at different interest rates, depending on survival probabilities (i.e. age). In order to keep the asset market structure simple and tractable we therefore decided to prevent agents from borrowing altogether.

described by the joint measure Φ_t over asset positions, labor productivity status, ability and age.

Therefore let $a \in \mathbf{R}_+$, $\eta \in \mathbf{E} = \{\eta_1, \eta_2, ..., \eta_n\}$, $i \in \mathbf{I} = \{1, \ldots, M\}$, $j \in \mathbf{J} = \{1, 2, ...J\}$, and let $\mathbf{S} = \mathbf{R}_+ \times \mathbf{E} \times \mathbf{J}$. Let $\mathbf{B}(\mathbf{R}_+)$ be the Borel σ-algebra of $\mathbf{R}_+$ and $\mathbf{P}(\mathbf{E})$, $\mathbf{P}(\mathbf{I})$, $\mathbf{P}(\mathbf{J})$ the power sets of $\mathbf{E}, \mathbf{I}$ and $\mathbf{J}$, respectively. Let $\mathbf{M}$ be the set of all finite measures over the measurable space $(\mathbf{S}, \mathbf{B}(\mathbf{R}_+) \times \mathbf{P}(\mathbf{E}) \times \mathbf{P}(\mathbf{I}) \times \mathbf{P}(\mathbf{J}))$.

Definition 1. *Given a sequence of social security replacement rates $\{b_t\}_{t=1}^\infty$, consumption tax rates $\{\tau_{c,t}\}_{t=1}^\infty$ and government expenditures $\{G_t\}_{t=1}^\infty$ and initial conditions K_1 and Φ_1, a competitive equilibrium is a sequence of functions for the household, $\{v_t, c_t, a'_t, \ell_t : \mathbf{S} \to \mathbf{R}_+\}_{t=1}^\infty$, of production plans for the firm, $\{N_t, K_t\}_{t=1}^\infty$, government income tax functions $\{T_t : \mathbf{R}_+ \to \mathbf{R}_+\}_{t=1}^\infty$, social security taxes $\{\tau_{ss,t}\}_{t=1}^\infty$ and benefits $\{SS_t\}_{t=1}^\infty$, prices $\{w_t, r_t\}_{t=1}^\infty$, transfers $\{Tr_t\}_{t=1}^\infty$, and measures $\{\Phi_t\}_{t=1}^\infty$, with $\Phi_t \in \mathbf{M}$ such that:*

1. *given prices, policies, transfers and initial conditions, for each t, v_t solves the functional equation (with c_t, a'_t and ℓ_t as associated policy functions):*

$$v_t(a, \eta, i, j) = \max_{c, a', \ell}\{u(c, \ell) + \beta\psi_j \int v_{t+1}(a', \eta', i, j+1)Q(\eta, d\eta')\} \qquad (4)$$

subject to:

$$
\begin{aligned}
c + a' = \;& (1 - \tau_{ss,t})w_t\varepsilon_j\alpha_i\eta\ell + (1 + r_t)(a + Tr_t) \\
& - T_t[(1 - \tau_{ss,t})w_t\varepsilon_j\alpha_i\eta\ell + r_t(a + Tr_t)], for \;\; j < j_r,
\end{aligned} \qquad (5)
$$

$$
\begin{aligned}
c + a' = \;& SS_t + (1 + r_t)(a + Tr_t) \\
& - T_t[SS_t + r_t(a + Tr_t)], for \;\; j \geq j_r,
\end{aligned} \qquad (6)
$$

$$a' \geq 0, c \geq 0, 0 \leq \ell \leq 1. \qquad (7)$$

2. *Prices w_t and r_t satisfy:*

$$r_t = \theta\alpha\left(\frac{A_tN_t}{K_t}\right)^{1-\alpha} - \delta, \qquad (8)$$

$$w_t = \theta(1 - \alpha)A_t\left(\frac{K_t}{A_tN_t}\right)^{\alpha}. \qquad (9)$$

3. *The social security policies satisfy*

$$SS_t = b_t\frac{w_tN_t}{\int \Phi_t(da \times d\eta \times di \times \{1, ..j_r - 1\})} \qquad (10)$$

$$\tau_{ss,t} = \frac{SS_t}{w_tN_t}\int \Phi_t(da \times d\eta \times di \times \{j_r, ..., J\}). \qquad (11)$$

4. Transfers are given by:

$$Tr_{t+1} = \frac{\int (1 - \psi_j) a'_t(a, \eta, i, j) \Phi_t(da \times d\eta \times di \times dj)}{\int \Phi_{t+1}(da \times d\eta \times di \times dj)} \tag{12}$$

5. Government budget balance:

$$
\begin{aligned}
G_t =\ & \int T_t[(1 - \tau_{ss,t}) w_t \varepsilon_j \alpha_i \eta \ell_t(a, \eta, i, j) + r_t(a + Tr_t)] \Phi_t(da \times d\eta \times di \times \{1, ..j_r - 1\}) + \\
& \int T_t[SS_t + r_t(a + Tr_t)] \Phi_t(da \times d\eta \times di \times \{j_r, ..., J\}) + \\
& \tau_{c,t} \int c_t(a, \eta, i, j) \Phi_t(da \times d\eta \times di \times dj)
\end{aligned} \tag{13}
$$

6. Market clearing:

$$K_t = \int a \Phi_t(da \times d\eta \times di \times dj) \tag{14}$$

$$N_t = \int \varepsilon_j \alpha_i \eta \ell_t(a, \eta, i, j) \Phi_t(da \times d\eta \times di \times dj) \tag{15}$$

$$\int c_t(a, \eta, i, j) \Phi_t(da \times d\eta \times di \times dj) + \int a'_t(a, \eta, i, j) \Phi_t(da \times d\eta \times di \times dj) + G_t =$$

$$K_t^\alpha (A_t N_t)^{1-\alpha} + (1 - \delta) K_t \tag{16}$$

7. Law of Motion:

$$\Phi_{t+1} = H_t(\Phi_t) \tag{17}$$

where the function $H_t : \mathbf{M} \to \mathbf{M}$ can be written explicitly as:

1. for all $\mathcal{J}$ such that $1 \notin \mathcal{J}$:

$$\Phi_{t+1}(A \times E \times \mathcal{I} \times \mathcal{J}) = \int P_t((a, \eta, i, j); A \times E \times \mathcal{I} \times \mathcal{J}) \Phi_t(da \times d\eta \times di \times dj) \tag{18}$$

where

$$P_t((a, \eta, i, j); A \times E \times \mathcal{I} \times \mathcal{J}) = \begin{cases} Q(e, E) \psi_j & \text{if } a'_t(a, \eta, i, j) \in A, i \in \mathcal{I}, j + 1 \in \mathcal{J} \\ 0 & \text{else} \end{cases} \tag{19}$$

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2.

$$\Phi_{t+1}((A \times E \times \mathcal{I} \times \{1\})) = (1+n)^t \begin{cases} \sum_{i \in \mathcal{I}} p_i & \text{if } 0 \in A, \bar{\eta} \in E \\ 0 & \text{else} \end{cases} \tag{20}$$

Definition 2. *A Balanced Growth Path is a competitive equilibrium in which* $b_t = b_1$, $\tau_{c,t} = \tau_{c,1}$, $G_t = ((1+g)(1+n))^{t-1} G_1$, $a_t'(.) = (1+g)^{t-1} a_1'(.)$, $c_t(.) = (1+g)^{t-1} c_1(.)$, $\ell_t(.) = l_1(.)$, $N_t = (1+n)^{t-1} N_1$, $K_t = ((1+g)(1+n))^{t-1} K_1$, $T_t = (1+g)^{t-1} T_1$, $\tau_{ss,t} = \tau_{ss,1}$, $SS_t = (1+g)^{t-1} SS_1$, $r_t = r_1$, $w_t = (1+g)^{t-1} w_1$, $Tr_t = (1+g)^{t-1} Tr_1$ *for all* $t \geq 1$ *and* $\Phi_t((1+g)^{t-1}A, E, \mathcal{I}, \mathcal{J}) = (1+n)^{t-1}\Phi_1(A, E, \mathcal{I}, \mathcal{J})$ *for all* t *and all* $A \in \mathbf{R}_+$. *That is, per capita variables and functions grow at constant gross growth rate* $1+g$, *aggregate variables grow at constant gross growth rate* $(1+n)(1+g)$ *and all other variables (and functions) are time-invariant.*[5]

Note that, in order to represent this economy on a computer, one first has to carry out the standard normalizations by dividing the utility function and the budget constraint by A_t to make the household recursive problem stationary.[6]

3. Functional Forms and Calibration of the Benchmark Economy

In this section we discuss the functional form assumptions and the parameterization of the model that we employ in our quantitative analysis.

3.1. Demographics

The demographic parameters have been set so that the model economy has a stationary demographic structure matching that of the US economy. Agents enter the economy at age 20 (model age 1), retire at age 65 (model age 46) and die with certainty at age 100 (model age 81). The survival probabilities are taken from Faber (1982). Finally, the population growth rate is set to an annual rate of 1.1%, the long-run average for the US. Our demographic parameters are summarized in Table I.

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Table I: Demographics Parameters

Parameter	Value	Target
Retir. Age: j_r	46(65)	Compul. Ret. (assumed)
Max. Age: J	81(100)	Certain Death (assumed)
Surv. Prob.	Faber (1982)	Data
Pop. Growth: n	1.1%	Data

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The maximum age J, the population growth rate and the survival probabilities together determine the population structure in the model. We chose J so that the model delivers a ratio of people older than 65 over population of working age as observed in the data.

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[5]The notation $T_t = (1+g)^{t-1}T_1$ should be interpreted as follows: an agent with income y in period 1, faces the same *average and marginal* tax rate as an agent with income $(1+g)^{t-1}y$ in period t.

[6]See e.g. Aiyagari and McGrattan (1998) for a detailed discussion of this normalization, for a model that is very similar to ours.

3.2. Preferences

We assume that preferences over consumption and leisure can be represented by a period utility function of the form:

$$U(c, \ell) = \frac{\left(c^\gamma (1 - \ell)^{1-\gamma}\right)^{1-\sigma}}{1 - \sigma}. \tag{21}$$

In order to calibrate the preference parameters we proceed as follows. First, we fix the coefficient of relative risk aversion to $\sigma = 2$. Then the discount factor β is chosen so that the equilibrium of our benchmark economy implies a capital-output ratio of 2.7 as observed in the data.[7] The share of consumption in the utility function is chosen so that individuals in active age work on average $\frac{1}{3}$ of their discretionary time. Preference parameters are summarized in Table II.

Table II: Preferences Parameters

Parameter	Value	Target
β	0.989	$K/Y = 2.7$
σ	2.0	Fixed
γ	0.373	Avg Hours= $\frac{1}{3}$

3.3. Endowments

In each period agents are endowed with one unit of time. Their labor productivity is composed of a type specific component depending on ability α_i, an age-specific average component ε_j and a idiosyncratic stochastic component η_t in a multiplicative fashion. The deterministic component of efficiency units of labor is taken from Hansen (1993). It features a hump over the life cycle, with peak at age 50.

For the ability and stochastic component of labor productivity we use a discretization, using the Tauchen and Hussey (1991) procedure, of the autoregressive process reported in Storesletten et al. (2000). They estimate the following process for the natural logarithm of household income $\ln(\eta_{it})$

$$\ln(\eta_{it}) = \alpha_i + z_{it} + \xi_{it} \qquad \xi_{it} \sim N(0, \sigma_\xi^2) \tag{22}$$

$$z_{it} = \rho z_{it-1} + \chi_{it} \qquad \chi_{it} \sim N(0, \sigma_\chi^2) \tag{23}$$

and find estimates of $(\rho, \sigma_\alpha^2, \sigma_\xi^2, \sigma_\chi^2) = (0.984, 0.242, 0.057, 0.022)$. For the ability component of labor productivity we choose two types, $M = 2$ with equal mass, $p_i = 0.5$ for $i = 1, 2$. Their ability levels (α_1, α_2) are chosen to match the estimate $\sigma_\alpha^2 = 0.242$, which yields as $\alpha_1 = e^{-\sqrt{0.242}}$ and $\alpha_2 = e^{\sqrt{0.242}}$. Thus wages for high ability agents are, on average, 46% higher than median wages and wages of low ability agents, correspondingly, 46% lower than median wages. We summarize the calibration of ability in Table III.

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[7]For model parameters that are calibrated using data and equilibrium observations of the model it is understood that all parameters jointly determine equilibrium quantities of the model. Our discussion relates a parameter to that equilibrium target which is affected most by the particular parameter choice.

Our measure of capital includes nonresidential fixed assets (equipment, software and nonresidential structures) as well as private residential structures and consumer durable goods. The data comes from the 2000 BEA Fixed Assets and Durable Goods tables.

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Table III: Ability

Parameter	Value	p_i
α_1	0.6115	0.5
α_2	1.6354	0.5

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For the stochastic component a discretization of the remainder of Storesletten et al.'s (2000) process into a seven state Markov chain, using Tauchen's method, yields results summarized in Table IV.[8]

<div align="center">

Table IV: Stochastic Productivity

Parameter	Value	Π
η_1	0.114	0.034
η_2	0.223	0.135
η_3	0.402	0.214
$\eta_4 = \bar{\eta}$	0.706	0.236
η_5	1.238	0.214
η_6	2.235	0.135
η_7	4.383	0.034

</div>

The associated transition matrix of the Markov chain is given by

$$Q(\eta, \eta') = \begin{pmatrix} 0.927 & 0.047 & 0.022 & 0.003 & 0 & 0 & 0 \\ 0.012 & 0.939 & 0.035 & 0.012 & 0.001 & 0 & 0 \\ 0.003 & 0.022 & 0.938 & 0.027 & 0.009 & 0.001 & 0 \\ 0.001 & 0.007 & 0.024 & 0.936 & 0.024 & 0.007 & 0.001 \\ 0 & 0.001 & 0.009 & 0.027 & 0.938 & 0/022 & 0.003 \\ 0 & 0 & 0.001 & 0.012 & 0.035 & 0.939 & 0.012 \\ 0 & 0 & 0 & 0.003 & 0.022 & 0.047 & 0.927 \end{pmatrix}. \tag{24}$$

3.4. Technology

We assume that the aggregate production function is of Cobb-Douglas form:

$$F(K_t, N_t) = K_t^\alpha \left(A_t N_t\right)^{1-a} \tag{25}$$

with capital share α, where we choose $\alpha = 0.36$, in accordance with the long-run capital share for the US economy. The depreciation rate is set to $\delta = 6.75\%$ so that in the balanced growth path the benchmark economy implies an investment to output ratio equal roughly to 26% as in the data.[9] Finally, since in a balanced growth path per capita GDP is growing at rate g, we choose $g = 1.75\%$ to match the long-run growth rate of per capita GDP for US data. Technology parameters are summarized in Table V.

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[8]We adjust the variances of Storesletten et al. (2000) in such a way that the cross-sectional dispersion of productivity, by age, generated by the discretized process corresponds to the one in the data, as reported in Figure 1 of Storesletten et al. (2000). Since the original Tauchen procedure did not generate enough variability and persistence we increased the variances fed into the procedure over the ones reported by Storesletten et al. and mixed the generated transition matrix with an identity matrix to increase persistence. Table 4 and associated transition matrix contains the result of this procedure.

[9]Notice that investment into consumer durables is included in aggregate gross investment.

Table V: Technology Parameters

Parameter	Value	Target
α	0.36	Data
δ	6.75%	$I/Y = 25.5\%$
g	1.75%	Data

3.5. Government Policies and the Income Tax Function

In order to parameterize the actual tax code we proceed as follows. First, we fix the proportional consumption tax rate to $\tau_c = 5.2\%$, which is the consumption tax rate found by Mendoza et al. (1994) for the US The level of government consumption, G, is chosen so that in a balanced growth path the government consumption share of GDP is 17.3%, as in the data.

The social security system is chosen so that the replacement rate (ratio of retirement pension to the average wage) is 50%. The implied payroll tax required to finance benefits, under the assumption of a balanced budget for the social security system, is uniquely pinned down by our assumptions about demographics, and is equal to $\tau_{ss} = 12.4\%$, as currently for the US, excluding Medicare.

The principal focus of this paper is the income tax code. We want to use an income tax code that provides a good approximation to the actual current tax code for the US and then, in our policy experiment, vary this tax code in order to find the hypothetical optimal tax code, given a particular social welfare function.

We use a functional form for the income tax code that is theoretically motivated by the equal sacrifice principle (see Gouveia and Strauss (1994)) and is fairly flexible in that it encompasses a wide range of progressive, proportional and regressive tax schedules. Letting $T(y)$ denote total taxes paid by an individual with pre-tax income y, the tax code is restricted to the functional form

$$T(y) = a_0 \left(y - (y^{-a_1} + a_2)^{-\frac{1}{a_1}} \right) \tag{26}$$

where (a_0, a_1, a_2) are parameters.

Note the following facts:

1.

$$\lim_{y \to \infty} \frac{T(y)}{y} = \lim_{y \to \infty} T'(y) = a_0 \tag{27}$$

so that the limiting marginal and average tax rate equals a_0.

2. For $a_1 = -1$, we obtain a constant tax independent of income

$$T(y) = -a_0 a_2 \tag{28}$$

3. For $a_1 \to 0$ we have a purely proportional system

$$T(y) = a_0 y \tag{29}$$

12

4. For $a_1 > 0$ we have a progressive system since:

$$t(y) \;=\; \frac{T(y)}{y} = a_0 \left(1 - (1 + a_2 y^{a_1})^{-\frac{1}{a_1}}\right) \tag{30}$$

$$T'(y) \;=\; a_0 a_2 y^{-a_1-1}(1 + a_2 y^{a_1})^{-\frac{1}{a_1}-1} \tag{31}$$

and thus marginal (as well as average) taxes are an increasing function of income y.

Gouveia and Strauss (1994) use this parametric class of tax function to approximate the current US system and obtain values of $a_0 = 0.258$ and $a_1 = 0.768$. The parameter a_2 is chosen so that the government balances its budget in the balanced growth path. Note that a_2 is not invariant to units of measurement: if one scales all variables by a fixed factor, one has to adjust the parameter a_2 in order to preserve the same tax function.[10] The policy parameters employed as benchmark are summarized in Table VI.

Table VI: Policy Parameters

Parameter	Value
τ_c	5.2%
a_0	0.258
a_1	0.768
b	0.5
τ_{ss}	12.4%

4. The Computational Experiment

We will define the optimal tax code as the tax code (within the parametric class chosen) with the highest ex-ante steady state expected utility of a newborn. With a given tax code T, parameterized by (a_0, a_1) since a_2 is implied by government budget balance (and fixing all other policies), is associated a balanced growth path with invariant measure $\Phi_T(a, \eta, i, j)$ and value function $v_T(a, \eta, i, j)$. Our social welfare function is then given by:

$$
\begin{aligned}
SWF(T) \;&=\; \int_{\{(a,\eta,i,j):a=0,j=1\}} v_T(a,\eta,i,j)d\Phi_T \\
&=\; \sum_{i \in \mathbf{I}} p_i v_T(a=0, \eta = \bar{\eta}, i, j = 1)
\end{aligned} \tag{32}
$$

and we aim at determining:

$$T^* = \arg \max_{(a_0,a_1)} SWF(T) \tag{33}$$

Numerically, this is done by constructing a grid in the space of policy parameters (a_0, a_1), computing the equilibrium and the associated expected utility of a newborn for every grid

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[10]The parameter a_2 depends on units in the following sense. Suppose that we scale income by a factor $\lambda > 0$ (i.e. change the units of measurement). In order to let the tax system be unaffected by this change one has to adjust a_2 correspondingly: $a_2 y^{a_1} = \tilde{a}_2 (\lambda y)^{a_1}$ and therefore $\tilde{a}_2 = a_2 \lambda^{-a_1}$.

point and finding the welfare-maximizing (a_0, a_1)-combination. In conjunction with this analysis we will compare macroeconomic aggregates in the balanced growth path associated with the optimal tax code with those arising in the balanced growth path of the benchmark tax code. This analysis can be found in the next section.

The first stage of our quantitative analysis is confined to a positive and normative comparison of balanced growth path allocations. In the second stage of our analysis, we explicitly compute the transitional dynamics induced by a reform from the benchmark economy towards the optimal tax code. In particular, starting from the initial balanced growth path we induce an unexpected change of (a_0, a_1) to their optimal levels (optimal in the sense of the first part of our analysis), and adjust a_2 along the transition path in order to guarantee government budget balance in every period. In Section 6 we first discuss the time paths of aggregate variables along the transition towards the new steady state. We then identify the winners and losers of the reform by computing the welfare consequences for agents of different ages and economic status that are alive at the time of the implementation of the tax reform. A brief discussion of the implied political economic consequences implied by the welfare calculations concludes our quantitative analysis.

5. The Optimal Tax Code

We find that the optimal tax code, as defined above, is described by $a_0 = 0.195$, $a_1 = 9.05$. Such a tax code is roughly equivalent to a proportional tax of 19.5% with a fixed deduction of about $3,700$. Figures 1 and 2 display the average and marginal tax rates implied by the optimal income tax code and, as comparison, of the benchmark income tax code.

Figure 1: Average Tax Rates under 2 Tax Systems
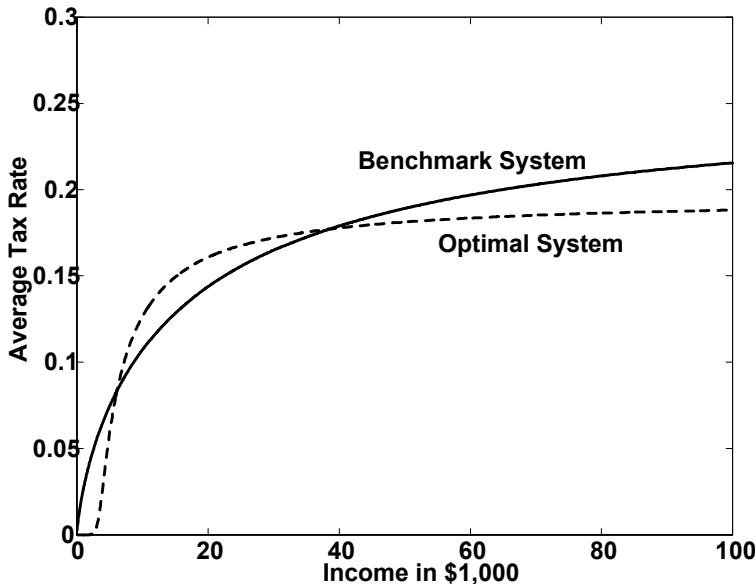
We see that marginal tax rates (and consequently average tax rates) in the optimal tax system are considerably lower for households in the upper tail of the income distribution, as

compared to the benchmark system. Also, due to the fixed deduction marginal tax rates are almost 0 for the first $3,700 of income under the optimal system.

Figure 2: Marginal Tax Rates under 2 Tax Systems
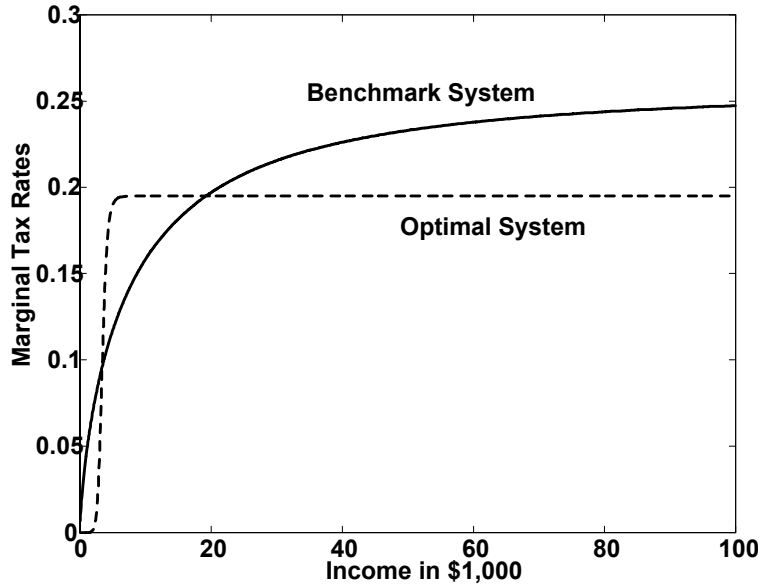
In order to assess how tax burdens differ in both system, in Figure 3 we plot the total dollar amount a household with particular income would pay less (or more) in income taxes under the new, as compared to the old system. We see that households with small and large incomes see their income tax burdens reduced, those with high incomes significantly, whereas households in the middle of the income distribution face a higher income tax bill. For example, a household with yearly income of $20,000 would pay roughly $350 more in income taxes per year under the new, compared to the old tax system.

Figure 3: Difference in Total Taxes Paid
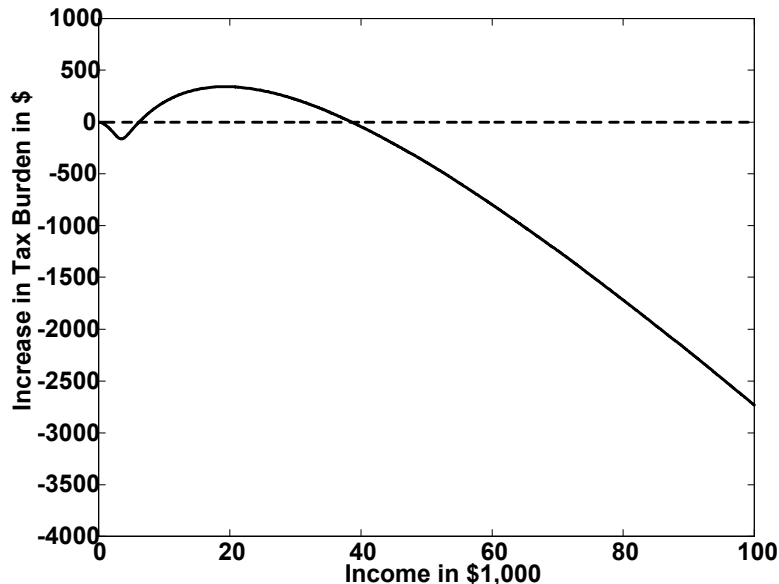
In order to obtain a better understanding for the economic forces underlying the results concerning the optimal tax code, in Table VII we compare the main macroeconomic aggregates associated with the optimal tax code with those obtained under the benchmark tax system. In order to isolate the efficiency from the insurance and redistribution effect it is also instructive to present the corresponding numbers for a pure proportional tax system, without exemption level.

In order to compare welfare across different tax systems, we compute and (as consumption equivalent variation CEV) the uniform percentage decrease in consumption, at each date and in each event (and fixed labor-leisure allocation), needed to make a household indifferent between being born into the balanced growth path associated with a particular tax system and being born into the benchmark balanced growth path. Positive CEV thus reflect a welfare increase due to a tax reform, compared to the benchmark system.[11]

Table VII: Comparison across Tax Codes

Variable	BENCH.	OPTIMAL	PROP.
Parameter a_0	0.258	0.195	0.166
Parameter a_1	0.768	9.05	0.0
Interest Rate r	6.54%	6.33%	6.07%
Average Hours Worked	0.331	0.333	0.344
Total Labor Supply N	1	1.018	1.039
Capital Stock K	1	1.043	1.099
GDP Y	1	1.027	1.060
Aggregate Consumption C	1	1.027	1.061
Gov. share in GDP $\frac{G}{Y}$	17.3%	16.9%	16.3%
Average Income Tax	17.6%	17.1%	16.5%
Gini Coef. for Pre-tax Income	0.480	0.493	0.486
Gini Coef. for After-tax Income	0.441	0.462	0.467
Gini Coef. for Gini Wealth	0.704	0.731	0.729
Gini Coef. for Consumption	0.345	0.360	0.365
ECV	0%	0.4%	−0.2%

Notice that the optimal tax code implies higher labor supply and, in particular, higher capital accumulation than the benchmark economy, and as a result GDP per capita is 2.7% higher. This reflects the reduced disincentive effects to work and save for the households at the high end of the income distribution, due to vastly reduced marginal income tax rates for that group. For the labor supply decision, for example, note that average hours worked increase by very little after the reform, but total labor supply increases by 1.8%, which is explained by the fact that it is high-ability, high-productivity agents which expand their labor supply in response to lower marginal tax rates for their income brackets. Finally, due to the increase in economic activity triggered by the tax reform the fraction of GDP devoted to government consumption and the average tax rate required to fund government outlays shrinks, leaving

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[11]All welfare numbers in the remainder of this paper refer to this welfare measure. We normalize total labor supply N, the capital stock K, output Y and consumption C such that the benchmark economy features values for these variables equal to 1.

a higher *fraction* of already higher output for private consumption and investment. In total, aggregate consumption increases by a substantial 2.7%.

Providing better incentives to work and save comes at the price of creating a more dispersed income, wealth and consumption distribution. Table VII documents this with the Gini coefficients for income, consumption and wealth. First, under the optimal tax system pre-tax income is more unequally distributed since high-ability, high productivity agents work and save disproportionately more under the new tax code (see also the wealth Gini). Second, the tax system provides less redistribution, so that the after-tax income Gini increases even more, due to the tax reform. Both effects lead to an increase in consumption inequality under the optimal, compared to the benchmark system. Consequently the BGP welfare gains of a tax reform are much smaller than the 2.7% increase in aggregate consumption may suggest.[12]

Nevertheless, since the optimal tax code provides sizeable welfare gains, but implies an increase in inequality relative to the benchmark tax code, as measured by the after-tax income, consumption and wealth Gini coefficients, one could view the benchmark tax code as "too" progressive. [13]

The comparison of the actual with a pure proportional tax system without deduction shows even more pronouncedly that in this economy there does exist a strong social desire for redistribution and insurance, which the optimal tax system reflects with the fixed deduction. Even though GDP per capita and aggregate consumption are 6% higher in a purely proportional system as compared the benchmark BGP, social welfare is lower under purely proportional taxes. Agents born into the new BGP with high ability (and average productivity) experience welfare gains of roughly 1.0%, but agents born with low ability would suffer significantly, by 1.3% in terms of consumption equivalent variation.

6. Transition to the Optimal Tax Code and Welfare Implications

In this section we shift attention to the quantitative implications of reforming the tax code towards the optimal found in the previous section, taking full account of the transition path induced by the tax reform. To do so we have to take a stand on how the tax code is adjusted as the economy moves from the old to the new balanced growth path. We assume that in period 1 the economy is in the BGP of the benchmark economy. Then, in period 2 an unanticipated tax reform is carried out, imposing $a_0 = 0.195$ and $a_1 = 9.05$ from then on. The parameter a_2 is adjusted in every period to satisfy budget balance at each date of the transition. Effectively, this amounts to a reform that imposes a constant marginal tax rate

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[12]Part of the reason for why a 2.7% increase in aggregate consumption leads only to a 0.4% increase in welfare is the increase in labor supply and thus the reduction in leisure that agents enjoy. This effect is relatively minor, however, because average hours worked hardly increase under the optimal tax system.

[13]It is important to point out here that our benchmark economy is roughly able to account for the observed wealth inequality. Castañeda et al. (2002) report a Gini coefficient of wealth of 0.78, whereas in our benchmark economy it amounts to 0.704.

The moderate divergence between the model and the data stems from the fact that the model is incapable of generating sufficiently high wealth concentration at the very top of the distribution.

As Castañeda et al. (2002) suggest, in a model like ours the presence of a pay-as-you-go social security system is crucial for our relative success of creating sufficient wealth inequality, since it significantly reduces the incentives of young and middle-aged agents to accumulate assets and thus leads to a large fraction of agents in these age cohorts with no financial assets.

of 19.5% and the fixed deduction is adjusted in every period so that the government collects enough revenues in order to finance a constant level of public consumption. Over time the economy converges to its new BGP, and the tax system to the one defined and computed as optimal in the previous section.[14]

6.1. Dynamics of Aggregate Variables

Figure 4 documents the evolution of macroeconomic aggregates along the transition path. On impact of the reform the aggregate capital stock is predetermined by the savings decisions in the previous period. Therefore, since the tax reform was unanticipated, the aggregate capital stock does not react immediately to the reform. However, aggregate labor supply increases on impact, due to the new lower marginal income tax rates for high-income earners. In the first reform period the increase in labor supply amounts to more than 2%, and converges to its new BGP level, which is roughly 1.8% higher than in the initial BGP. As a consequence of the increase in labor supply and an initially fixed capital stock the capital-labor ratio falls and interest rates rise on impact. Then, as capital accumulation picks up and the capital stock increases by about 4.3% in the new, as compared to the old BGP, the interest rate falls below the initial BGP level (and wages increase above the initial BGP level).

**Figure 4: Evolution of Aggregate Variables along the Transition**
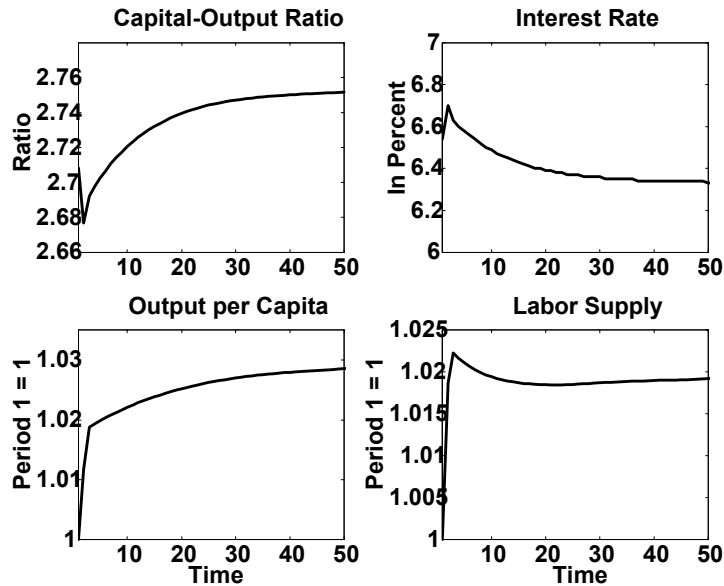
Notice that total GDP and thus per capita GDP is monotonically increasing along the transition path, due to both the expansion of labor supply and stronger capital accumulation. With per capita income the income tax base grows along the transition path (over and above the long-run growth rate of the economy, g). This transitional acceleration of economic growth explains why the tax deduction can be monotonically expanded over time as well,

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[14]A detailed description of the computational method employed to compute transition paths for our economy is available upon requests by the authors. The method is identical to the one used by and documented in Conesa and Krueger (1999) for a similar economy.

without increasing marginal taxes, reducing government outlays or violating the government budget constraint.

Figure 5 displays the time pattern of the deduction along the transition path. It mirrors the evolution of income per capita, starts at a level slightly above $3,000 and monotonically increases until its final steady state value of $3,700.

**Figure 5: Evolution of the Tax Deduction along the Transition**
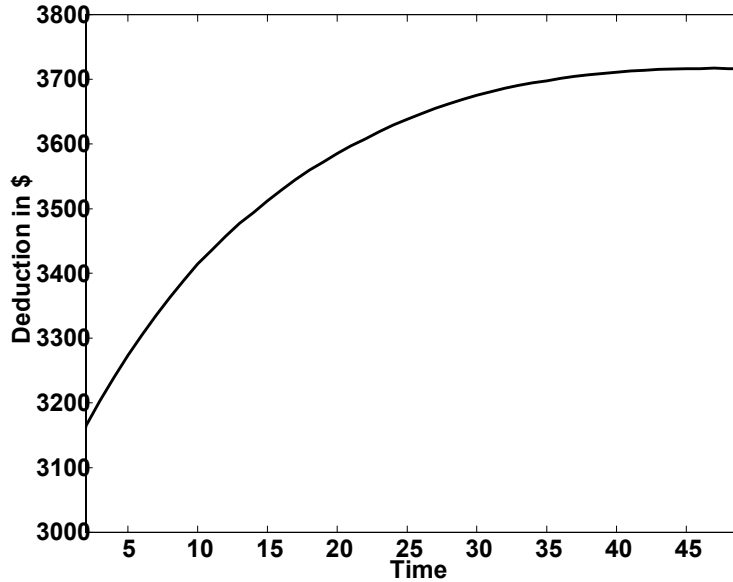
6.2. Welfare Consequences of the Reform

Explicitly considering the transitional dynamics induced by a fundamental tax reform allows us to evaluate the welfare implications of such a reform *for all individuals alive* at the moment the reform is implemented (rather than for agent born directly into the new balanced growth path, as in the previous section). Such an analysis may also shed some light on the political feasibility of a hypothetical reform.

Who gains from a potential reform? The income-richest and agents at the very bottom of the income distribution. Individuals with bad productivity realizations and very few assets gain from the reform because of the deduction whereas individuals with average productivity realizations and few assets lose with the reform. Finally, individuals with high productivity and/or large asset holdings and thus high labor and/or capital income invariably benefit from the lower marginal tax rates induced by the reform. In the light of Figure 3 (which shows the change of the tax burden across income) and Figure 5 (which demonstrates that the tax system along the transition path mimics that of the final BGP fairly closely) these results are not unexpected.

However, even though a reform towards a flat tax with deduction promises significant balanced growth path welfare gains, our numerical analysis of the transition path indicates that only 20% of the population alive at the date at which the reform is undertaken will experience welfare gains from the reform. Figure 6 displays the fraction of the population in each age cohort that experiences welfare gains.

Figure 6: Fraction of Cohort with Welfare Gains
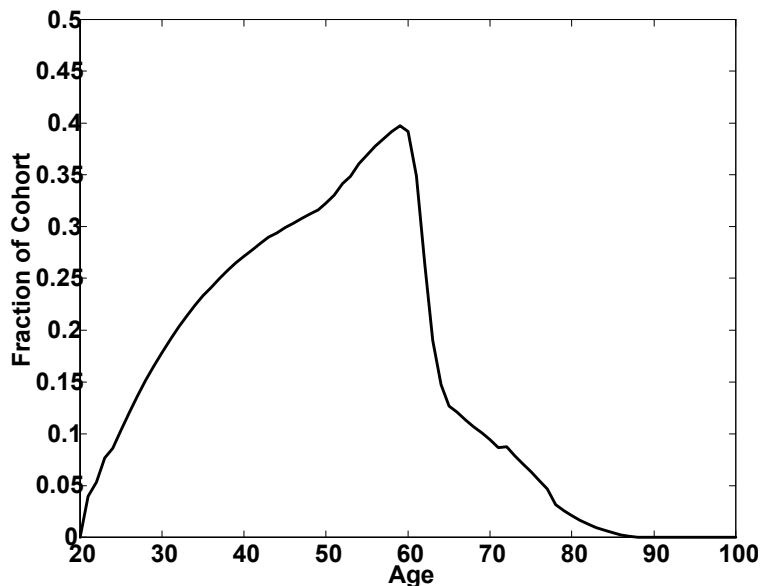
Notice that the fraction of individuals with welfare gains is increasing until the age of 60 after which it drops quite fast to zero. In particular, among the younger generations almost everybody experiences welfare losses from a potential reform. This has two reasons. First, young individuals are born with average productivity shock and have no assets, are therefore placed in the lower middle class of the income distribution, and thus do not benefit from the reform. Then, some households receive favorable and persistent productivity shocks as they age, become income- and wealth-rich and thus benefit from the reform. Other agents receive bad (and persistent) productivity shocks, move to the bottom of the income distribution and start to value the deduction. Second, and related to the first reason, as a household ages more and more idiosyncratic income uncertainty is revealed, and the insurance motive of the progressive benchmark system becomes less and less important, which helps to explain increased support of a tax-progressivity-reducing reform as a cohort ages.

Why does the previous argument not lead to positive welfare consequences of a tax reform for agents approaching or living in retirement? Individuals start to reduce their asset holdings after the age of 55, and labor earnings are also falling after that age because both efficiency units and hours worked decline. Thus, as the cohort lives through its 60's and 70's more and more of its members fall into middle income brackets, with higher implied tax burden under the new compared to the old income tax system.

The results of our model indicate that a fundamental tax reform towards a flat tax with deduction may be desirable for generation born in the far future, but is likely to face opposition from a majority of agents alive at the time of the reform.

7. Conclusion

In this paper we have demonstrated, using a computable stochastic dynamic general equilibrium model, that under a utilitarian social welfare function the optimal income tax code is well approximated by a flat tax rate schedule with a fixed deduction of roughly $3,700$.

Such a system implies lower marginal rates for high-productivity individuals as compared to the current US tax code, and thus reduces the distortionary effects on labor supply and capital accumulation originating from high marginal income tax rates for households in the upper tail of the income distribution. At the same time, the deduction pays tribute to the social desire for equity and provides insurance against idiosyncratic labor income uncertainty. Compared to the actual system, under the optimal tax system tax burdens would be reduced for households in the lower and upper tail of the income distribution, whereas the middle class would face a higher income tax bill. The long run welfare gains of a fundamental tax reform towards a flat tax seem sizeable, in the order of 0.4% uniformly higher consumption.

Are there large sums of money left on the table by not embarking on such a tax reform? The second part of our analysis, based on an explicit calculation of the transition path induced by such a reform casts doubts on this conjecture. Only 20% of the individuals initially alive would experience welfare gains. In particular the group of the US population usually referred to as the middle class and retired households would almost unambiguously lose out, calling into question whether fundamental tax reform towards a flat tax is politically feasible, and in fact desirable from a normative point of view.

There are several directions in which our analysis could be extended. In deriving our normative results we necessarily have to take a stand on the social welfare function which aggregates well-being of the heterogeneous population in our model. We conjecture that employing an alternative social welfare function which places more weight on individuals at the lower end of the distribution than a utilitarian functional would (e.g. a Rawlsian welfare function) would favor a more progressive income tax system than the one we have identified as optimal.

In addition, our findings that the welfare benefits of a flat tax reform are overturned by an explicit consideration of the transition make it desirable to derive the optimal *evolution* of the income tax system over time. This, however, would require, even in the parametric class of tax functions considered in this paper, to optimize over the tax function parameters in each period until a new, endogenously determined balanced growth path is reached, which seems computationally infeasible at this point.

Finally, an extension of the current model to incorporate aggregate fluctuations would allow us to quantify the importance of progressive income taxes as automatic stabilizer of business cycles, and thus to assess whether the intertemporal smoothing of aggregate shocks may provide an additional normative rationale that justifies the extent of tax progressivity which currently characterizes the US income tax code. However, to very frequently solve a model with aggregate fluctuations and endogenous savings as well as labor supply decisions (in order to determine the optimal tax code) appears to be as infeasible as the previously suggested exercise with the current level of available computing technology. We therefore defer these extensions to future research.

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