The Optimal Progressivity of Income Taxes for Couples

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Abstract

The existing U.S. tax code differentiates between single and married households. However, most work in the literature on optimal tax progressivity ignores this and only considers single individuals. This paper computes the optimal tax progressivity for single and married households in a life cycle general equilibrium model. This analysis shows that the optimal tax system is significantly more progressive than the system currently in place in the United States. It also features less progressive taxes on married households compared to singles, in contrast to the existing U.S. tax system. The reason is that the self-insurance in marriage partly substitutes for public insurance. Moreover, neglecting the presence of married households in the model results in a suboptimal level of tax progressivity. The paper also studies the effects of the option to file taxes separately on optimal progressivity. This option substantially reduces the optimal progressivity for couples. The choice of filing separately or jointly hinges on the couples' income ratio. Since couples face idiosyncratic wage shocks together and hence their income ratio varies every period. The option of filing status provides flexibility for couples to better insure the joint-income shocks by minimizing their tax burdens. Such an option limits the need for redistributive public insurance for couples. In addition, the reduced tax revenue collection caused by the tax filing option pushes down the progressivity to finance government expenditure.

1 Introduction

The current U.S. income tax schedule is progressive, where incomes are taxed at an increasingly higher rate, while transfers are skewed towards the poor. A progressive tax system can raise social welfare by offering social insurance against ex-ante heterogeneity and earnings uncertainty. However, it also implies distortions to labor supply and savings decisions, as increasing marginal tax rates reduce incentives to work and save. These distortions limit the optimal degree of progressivity.

Most work in the literature on optimal tax progressivity only considers single male individuals but ignoring females and married couples. However, after year 2000, female labor supply stands at about 1400 annual hours compared to 1900 annual hours for male, and about 75% of households feature two earners (See Figure 1). The inclusion of females in the analysis leads to an additional trade-off regarding progressivity. On the one hand, the higher elasticity of labor supply and labor participation cost for females increase the distortion of progressivity. On the other hand, females, on average, have a lower income than male counterparts. Therefore, inequality in an economy with both males and females is higher, which tends to increase optimal progressivity.

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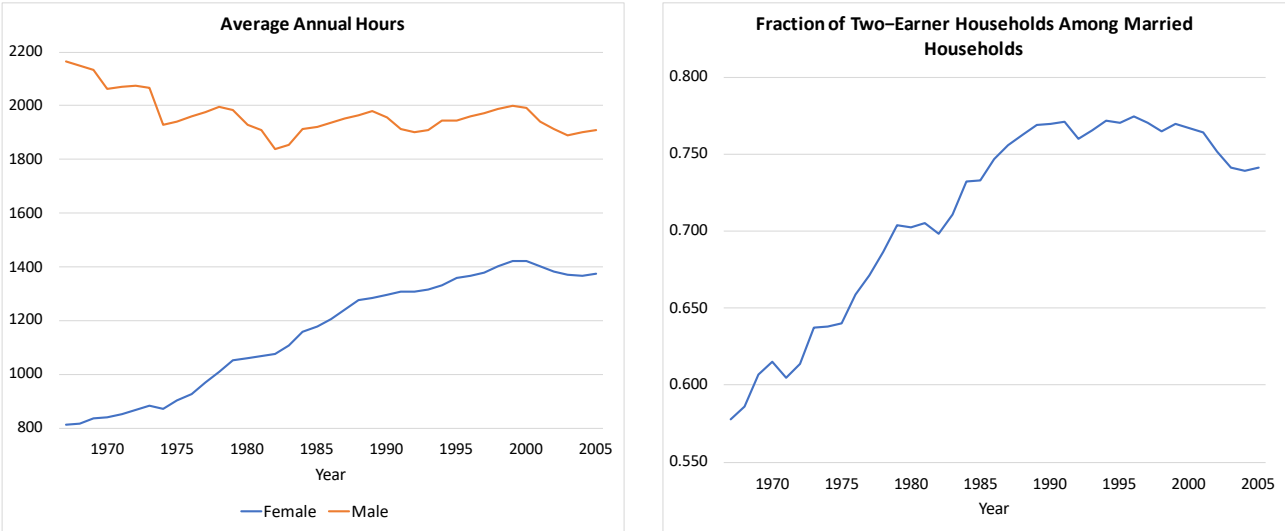


Source: Heathcote et al. (2010)

Figure 1: Rising female labor supply and two-earner households

There are benefits that only couples can enjoy, for example, economies of scale in consumption and private insurance against labor market and longevity risks. Therefore, couples behave differently compared to singles in terms of saving and labor supply. Moreover, a progressive tax system has an opposite impact on the low income group depending on a person's marital status. For instance, a more progressive system favors a low-earning single woman but not a low-earning married woman with a high earning husband. The former will benefit from a lower marginal tax rate while the later will suffer from a higher marginal tax rate induced by her high earning husband if they are taxed with joint income. Besides, couples have a better self-insurance against productivity risks compared to the single counterpart. As a result, the insurance role of progressive tax policy could be partly substituted by the self-insurance in marriage. Considering married couples in the context of optimal tax progressivity is therefore important, in particular, the increasing trend of assortative mating on educational attainment and the rising female labor supply are the major concerns. First of all, Greenwood et al. (2014) empirically find that the rising female labor supply amplifies the negative impact of assortative marriage on income inequality. A more dispersed income distribution pushes up the progressivity for a more even redistribution. Second, in the case of taxing with joint income where the marginal tax rate is the same for both spouses of the same couple. This typically results in higher marginal tax rates for low-income women as the income of the second earner is pooled with that of the high-income first earner. This distorts the labor participation of the second earner. However, such a distortion could be reduced since there will be more two earners households with similar income level due to assortative matching. If female labor supply and assortative matching keep rising, the optimal progressivity should be increasingly higher than that suggested by standard macroeconomic models without couples. Unfortunately, these important features are neglected in the literature studying optimal tax progressivity.

In fact, the existing U.S. tax code differentiates between single and married households. Married couples in

the United States have the options of either "Married Filing Jointly" or "Married Filing Separately"[1], the latter is not the same as that of unmarried individuals face. For the option of filing jointly, tax liability depends on total family income. For the option of filing separately, the tax liability is assessed separately for each family member and is therefore independent of the income of a spouse. Therefore, using a single representative tax system to analyze optimal progressivity implies ignoring a key feature of reality. This institutional tax feature could also affect optimal progressivity.

This paper highlights four key features that the literature ignored but matter to the optimal progressivity of a redistributive tax system. They are (1) gender and marital status; (2) the degree of assortative matching; (3) higher female labor supply elasticity and participation cost; (4) the option of taxing with separate income.

The inclusion of females and couples in the analysis leads to an additional trade-off regarding progressivity. Couples enjoy the economies of scale in consumption and better self-insurance ability while singles are more vulnerable to income shocks. Moreover, couples and singles are subject to two different tax systems. The optimal degree of tax progressivity taking into consideration of gender and marital status could be very different from that of a model using a single male household with a single representative tax system.

Matching is positively assortative in the dimension of educational attainment. People are more likely to match with similar education background, and hence they have a similar income. Under joint filing tax, the distortion on the labor supply of second earner is reduced because the marginal tax rate of the second earner is less (more) affected by the first earner for couples with similar (disparate) income. For couples with disparate income, a high-income first earner raises the marginal tax rate imposed on a low-income second earner. What's more important is that assortative matching increases income and consumption inequality. As a consequence, the degree of assortative matching plays an important role in determining optimal progressivity.

Empirical evidence shows that the secondary earners, in general, have a higher elasticity of labor supply (Blundell & MaCurdy 1999, Keane 2011). Therefore, higher tax progressivity implies a larger distortion to female labor supply. The degree of distortion hinges on the female labor supply elasticity and participation cost.

The fact that U.S. income tax schedule for married couples is non-marriage-neutral. It tends to penalize couples with spouses whose individual incomes are similar, while it benefits those whose incomes are farther apart. The option of filing separately provides an alternative for married couples to reduce the tax penalty. This paper investigates the effects of the option to file taxes separately on optimal progressivity.

This paper computes the optimal tax progressivity for single and married households. I address these questions in an overlapping generations life cycle model with incomplete markets and endogenous labor supply along the intensive and extensive margins. The economy is populated by single and married households that are subject to uninsurable idiosyncratic risk. Individuals do not have access to contracts contingent on future outcomes. They can, however, insure against adverse economic outcomes by savings. Each household has to make a decision on labor market participation (extensive margin), and working hours conditional on participation (intensive margin). Transfers and government expenditures are financed by taxes levied on labor and capital income, and

[1] Although couples can choose to be taxed separately, Survey of Consumer Finance (SCF) shows that there are only 4.7% of married couples choosing "Married Filing Separately" in 2001. The fact that a small share of married households choosing separate file is the reason for most papers to assume couples filing jointly only.

consumption. The set of tax policies is restricted to a particular functional form with two parameters (Benabou 2002, Heathcote et al. 2017a). The tax schedule used here not only provides a good fit to the current U.S. system but also allows for varying the level of tax rates and its progressivity separately.

The approach to characterize the optimal tax progressivity is primarily quantitative and is in the tradition of Ramsey (1927). The social planner maximizes the total welfare of all individuals in the economy by choosing the progressivity of the tax policy subject to a balanced budget constraint and optimal responses by households to the tax policy.

Using the calibrated model economy, I quantify the relative contribution of the four features mentioned above to the optimal degree of progressivity by conducting counterfactual experiments for economies where different features are introduced individually or in different combinations. The potential interactions of those features to the redistributive and efficiency consequences of the tax system can be disentangled.

The first main quantitative result is that a utilitarian government, under the benchmark parameterization, chooses higher progressivity than embedded in the U.S. tax and transfer system. The values of tax progressivity for singles and married couples that maximize social welfare are 0.17 and 0.12 respectively. The average welfare gain from increasing progressivity from the current U.S. value of 0.08 and 0.092 to the optimal is equivalent to 1.48% increase in consumption across all agents and all states of the world. Moreover, the optimal tax system features less progressive taxes on married households compared to singles, in contrast to the existing U.S. tax system. The reason is that the self-insurance in marriage partly substitutes for public insurance.

The degree of progressivity is limited by the distortions to labor supply and saving. The more progressive tax system crowds out precautionary savings, which results in lower steady-state capital stock and thus higher interest rate. The general equilibrium effect on overall welfare change is absent in a static model setting where there is no effect of capital accumulation on returns to saving (as in Gayle & Shephard 2016). In particular, when self-insurance via savings is available, the resulting increase in interest rate can improve social welfare by affecting the savings motives. A more progressive system further incentivizes the poor to save even more by reducing tax rates on their returns to savings. Such a general equilibrium effect is so strong that it improves welfare significantly in terms of a 1.2% increase in consumption.

The aggregate variables reveal the fact that the current U.S. tax system puts too much weight on efficiency at the expense of equity. The social planner who is averse to inequality in utility from consumption chooses a more progressive system to combat consumption inequality by providing more insurance against uninsurable shocks and ex-ante heterogeneity. The desire for redistribution and insurance is quantitatively reflected in the counterfactual experiment that a flat tax without transfer leads to a reduction in welfare by 3.32% of consumption, compared to the US benchmark, even though aggregate output increases by 5.7% compared to the benchmark.

The second main quantitative result is that the optimal tax code for couples should be less progressive than that of singles, contrary to the U.S. tax system. This difference can be attributed to two issues: (1) the insurance role of the married couples for income and longevity risk; (2) the extensive margin of labor supply for females.

In the first place, married couples' need for protection through progressive taxation and social insurance is limited relative to single households. Every working-age individual experiences productivity shocks and every

retiree faces mortality risk. Members of a married household are subject to the risks of both partners. However, they can effectively self-insure more productivity risk by saving and by choosing whether to work and how many hours for themselves. However, single households do not have partners to share the risk. Therefore, the ability to hedge against the adverse outcomes for married households is more effective than that of single households. Furthermore, since a married individual inherits her spouse's wealth after his death and the likelihood that both partners survive to very old age is relatively small, marriage serves as an insurance device against longevity risk for the surviving partner. Consequently, the need for public retirement benefits is limited to married couples.

In the second place, the effect of progressivity on labor supply differs for married and for single women. The low earners benefit from a more progressive tax system due to the lower average and marginal tax rates. Therefore, single females with low wages benefit more from work and even start to participate. In opposite, when a family is taxed jointly, and if a husband has high earning while a wife has low earning, it is potentially optimal for the wife not to work under a more progressive tax system. As a result, the optimal tax progressivity for singles should be more progressivity than that of the couples.

The third main quantitative result is that neglecting the presence of married households in the model results in a heavily suboptimal level of tax progressivity. This paper also takes the first step to study the effects of tax filing separately on the optimality. A detailed decomposition shows that the choice of tax filing separately substantially reduces the optimal progressivity for couples. The choice of filing separately or jointly hinges on the couples' income ratio. Since couples face idiosyncratic wage shocks together and hence their income ratio varies every period. The option of filing status provides flexibility for couples to better insure the joint-income shocks by minimizing their tax burdens. Such an option limits the need for redistributive public insurance for couples. In addition, not only can married households minimize their tax liability which reduces the tax revenue, the second earners are also encouraged to participate in the labor market which results in higher output and so does higher government expenditure. The burden of financing more government expenditure play a significant role in limiting optimal progressivity.

This paper contributes to the Ramsey-style literature that investigates the determinants of optimal progressivity in heterogeneous-agents incomplete-markets economies. The approach here is closest to Conesa & Krueger 2006, Conesa et al. 2009, who calculate the optimal progressivity of income taxes for an OLG economy with incomplete markets and heterogeneous agents. Heathcote et al. (2017a) take a similar approach to investigate the determinants of optimal progressivity in a Blanchard–Yaari–Bewley economy with partial insurance, and without capital. Bakış et al. (2015) compute the optimal non-linear tax policy along the transitional path for a dynastic economy with uninsurable risk. The main shortcoming of these papers was the missing of married households and the institutional features of the U.S. tax system. Given the fact of rising female labor supply and two-earner household share, using a single representative tax system to analyze optimal progressivity will provide a misleading policy evaluation. The institutional tax feature could also affect optimal progressivity.

Another strand of the literature studying optimal design of tax schedules for married couples focused mainly on the jointness of a tax schedule (Gayle & Shephard 2016, Frankel 2014, Kleven et al. 2009). These papers

apply Mirrleesian approach[2] to characterize the optimal form of jointness, which is defined as the change in marginal tax rates with respect to partner's earnings. These papers find that marginal tax rates should decline in partner's earnings. Gayle & Shephard (2016) non-parametrically characterize the optimal form of the tax system for both singles and couples but not focusing on the trade-off of optimal progressivity. In addition, their model environment is static where self-insurance via capital accumulation and the insurance role of marriage in the life cycle is missing. In contrast, my paper shows that the self-insurance in marriage plays a key role in determining the optimal tax progressivity of couples.

This paper also relates to the issue of family structure and income inequality. Greenwood et al. (2016) analyzed the importance of educational attainment, married female labor force participation, and marital structure in determining income inequality. Female labor participation amplifies the impact of assortative matching on income inequality as shown by Greenwood et al. (2014). Since assortative matching leads to a more dispersed household income and consumption distribution, a more progressive tax system is required to reduce the inequality. However, a quantitative approach for studying the impact of assortative matching on tax progressivity appears to be absent. This paper takes the initiative to quantify the contribution of assortative matching to optimal progressivity.

The remainder of the paper is organized as follows. Section 2 describes the model and formally defines the optimal taxation problem. Section 3 explains the calibration and estimation of the model parameters. Section 4 presents the optimal tax policy based on the comparison of benchmark economies and Section 5 shows how key model features affect results. Section 6 concludes.

2 The Model Economy

I adopt a general equilibrium model for the analysis by employing an overlapping generations life cycle model to compute the optimal tax progressivity for singles and married couples. Time is discrete and one model period is five years.

2.1 Demographics

The economy is populated by J overlapping generations of finitely lived households with age indexed by $j \in J$. To capture the heterogeneity in family structure, individuals are distinguished by their marital status of either single (indexed by S) or married (indexed by M), and their gender of either male or female, denoted as $g \in (m, f)$. There are three types of households in the economy: married couples, single males and single females. For simplicity, members of each married household are of the same age. The population of men and women are normalized to be 1. Before the start of the economy, a fixed proportion φ of men and women are married and never divorce, and the remaining $1 - \varphi$ are single and never marry. All households start working at age 20, after that they retire at age $J_r = 65$ and receive social security benefits up to maximum age $J = 100$.

The probability of dying during working periods is assumed to be zero while retired households are subject to a gender and age-specific probability of dying, $s_{g,j}$.

[2]The use of Mirrlessian approach (non-parametric) limits the complexity of the model environment, in particular, the model setting of papers using this approach is static but not dynamic.

2.2 Endowments and preferences

Households are heterogeneous with respect to the marital status, m, the gender, g, the age, j, the asset holdings, k, the average historical earnings, $\tilde{e}$, the permanent earning ability, and idiosyncratic productivity shocks z. Heterogeneity in characteristics of gender, marital status and permanent ability are invariant over the life cycle.

There is an exogenous positive assortative matching in the marriage market. Women with high (low) educational attainment are more likely to marry with men with high (low) educational attainment. The proportion of educational attainment combination within households is exogenously determined before the start of the economy.

Agents are endowed with one unit of productive time in each period of their life and enter the economy with no assets. Agents work for the first 45 years (equivalent to 9 periods) of their lives, after which they retire. I assume that men always work positive hours during working age. However, a woman will either work or stay at home. Married households jointly decide on how many hours to work, how much to consume, and how much to save.

Individuals have preferences over stochastic streams of consumption c_j and leisure $1 - n_j$, which they value according to the standard discounted expected utility function: $E[\sum_{j=1}^{J} \beta^{j-1} u(c_j, n_j)]$. The functional form of an individual utility u is assumed to be additively separable:

$$u(c, n) = \frac{c^{1-\sigma_c}}{1-\sigma_c} - \theta \frac{(n + \phi \mathbf{I}_{g=f,n>0})^{1+\epsilon}}{1+\epsilon}$$

where β is the discount rate, σ is the coefficient of relative risk aversion, ϵ is the gender-specific Frisch elasticity of labor supply and θ is the disutility of work. The fixed cost of working, ϕ is assumed to be zero for men, and thus there is an interior solution for male labor supply. The fixed cost of working for female can be interpreted as time cost for childcare, housework and so on.

Agents can smooth consumption over time and privately insure against labor income shocks by saving a risk free asset k without borrowing $k \geq 0$. For married individuals that die during retirement period, they leave savings to their remaining spouse. For singles and married couples that both die at the same age, they leave accidental bequests b_t. The government collects accidental bequests at the end of period t and uniformly distributes the bequests to all working-age individuals in the same period.

2.3 Income process

Following Bakış et al. (2015), the process for labor efficiency units is estimated by the following equation:

$$\ln z_{dit} = m_z + f_{di} + a_{dt}$$

where d indexes dynasties, i generations and t time. $f_{di} \in \{f_L, f_H\}$ denotes the permanent component of productivity, which remains fixed during each individual's life, and $a_{dt} \in \{a_L, a_H\}$ denotes the life-cycle component of productivity, which may change from period to period. Let $F = [F_{ij}]$ and $A = [A_{ij}]$ with $i, j \in \{L, H\}$ be 2-by-2 transition matrices associated with the two components f and a. The initial distribution of permanent components is taken from the estimation of matrix Π_F and individuals randomly draw the value of f from it

when they enter the economy. With this formulation, idiosyncratic fluctuations in labor income risk along the life cycle are captured by A, and those across generations by F. The following matrices summarize the stochastic labor productivity process over the life cycle and across generations

$$\Pi_A = \left(\begin{array}{c|cccc} & f_L + a_L & f_L + a_H & f_H + a_L & f_H + a_H \\ \hline f_L + a_L & A_{LL} & A_{LH} & 0 & 0 \\ f_L + a_H & A_{HL} & A_{HH} & 0 & 0 \\ f_H + a_L & 0 & 0 & A_{LL} & A_{LH} \\ f_H + a_H & 0 & 0 & A_{HL} & A_{HH} \end{array}\right)$$

$$\Pi_F = \left(\begin{array}{c|cccc} & f_L + a_L & f_L + a_H & f_H + a_L & f_H + a_H \\ \hline f_L + a_L & F_{LL} & 0 & F_{LH} & 0 \\ f_L + a_H & F_{LL} & 0 & F_{LH} & 0 \\ f_H + a_L & F_{HL} & 0 & F_{HH} & 0 \\ f_H + a_H & F_{HL} & 0 & F_{HH} & 0 \end{array}\right)$$

The initial distribution of permanent components for singles is

$$\int d\Gamma^S(j = 1, k = 0, z = f_L, \tilde{e} = 0, g = \{m, f\}) = \frac{F_{LL} + F_{HL}}{F_{LL} + F_{HL} + F_{LH} + F_{HH}}$$
$$\int d\Gamma^S(j = 1, k = 0, z = f_H, \tilde{e} = 0, g = \{m, f\}) = \frac{F_{HH} + F_{LH}}{F_{LL} + F_{HL} + F_{LH} + F_{HH}}$$

All the new households are assumed to start their career at lower productivity a_L, and get promoted later as their careers progress. Hence, the second and fourth column elements of Π_F are zero. This helps generate wage growth over the life cycle. It is also consistent with a higher variance of wages for older workers.

2.4 The government and tax policies

The government uses a nonlinear income tax and transfer system to provide social insurance and to finance the implied government expenditures G, social security expenses and transfers to households. Consumption is taxed at flat rate τ_c while labor, capital and pension income are subject to a progressive tax system.

The functional form used for the progressivity tax system in this paper is proposed by Benabou (2002), Heathcote et al. (2017a) show that this functional form offers a good approximation of the actual tax and transfer system in the United States. Let $T(y)$ be the tax function at pre-tax income level y relative to average labor income in the economy. The optimal degree of progressivity is analyzed within the class of tax and transfer policies defined by the function

$$T(y) = y - \lambda y^{1-\tau}$$

The tax system is progressive when $\tau > 0$ while it is regressive when $\tau < 0$. When $\tau = 0$, the system becomes a proportional tax (or flat tax) system with rate $1 - \lambda$. Notice that there are two key restrictions embedded in

$T(y)$: marginal tax rates are monotonic in income and lump-sum cash transfers is not allowed due to $T(0) = 0$[3].

This class of policies has been commonly applied into dynamic macroeconomic models with heterogeneous agents (Benabou 2000, 2002; Bakış et al. 2015; Heathcote & Tsujiyama 2015; Heathcote, Storesletten & Violante 2017a,b) The advantage of applying this functional form is that a single parameter τ measures the degree of tax progressivity which is not confounded by the level of tax rates λ. This is a desired feature for analyzing optimal progressivity since the government budget is balanced through adjustments of the level of income tax rate λ holding the degree of progressivity constant.

The tax function above also allows for negative taxes or transfers. There exists a threshold income level such that the average tax rate is negative for every income level below (above) the threshold if the system is progressive (regressive). Income transfers are, however, non-monotonic in income. When taxes are progressive, transfers are first increasing, and then decreasing in income. Examples of such transfers schemes include the earned income tax credit, welfare-to-work programs etc.

2.5 Social security benefits

The Social Security benefit at age 65 is calculated to mimic the Old Age and Survivor Insurance (OASI) component of the year 2000 Social Security system. Let b_1 and b_2 be the bend points, expressed as multiples of average earnings, for the 3 replacement rate brackets (90%, 32%, and 15%) that calculate the primary insurance amount (PIA) from the average historical earnings $\tilde{e}$.

$$SS(\tilde{e}) = \psi \min\{SS^{cap}, 0.9 \min(\tilde{e}, b_1) + 0.32 \max[\min(\tilde{e}, b_2) - b_1, 0] + 0.15 \max(\tilde{e} - b_2, 0)\}$$

where SS^{cap} is the maximum receivable pension benefits and ψ is an OASI benefit adjustment factor, which is calibrated to match the ratio of social security expenditure to GDP in the data. For simplicity, I abstract the social security spousal and survivorship benefits[4] from the model by pooling the average historical earnings within a marriage.

2.6 The single household decision problem

Agents value consumption and leisure. The problem of an agent is to choose labor supply, consumption and savings to maximize the expected present value of lifetime utility. At each period j, agents are informed of their labor productivity for the period $z_g \varepsilon_{g,j}$ prior to taking their decisions. Future utility is discounted with a constant factor $\beta \in (0, 1)$. Formally, the Bellman equation for a single worker's problem is:

$$V^S(j, k, z_g, \tilde{e}, g) = \max_{c,k',n} \left\{ u(c, n + \phi \mathbf{I}_{g=f,n>0}) + \beta \mathbb{E}\left[V^S(j+1, k', z_g', \tilde{e}', g) | z_g \right] \right\}$$

subject to

$$(1 + \tau_c)c + k' = k + y_S^d(w z_g \varepsilon_{g,j} n, rk)$$

[3]Heathcote & Tsujiyama (2015) show that the best policy in the class described above generates 84 percent of the maximum possible welfare gains from tax reform. Thus, the restrictions implicit in the tax function are not quantitatively important.

[4]The secondary earner receives either his or her own old-age retirement benefit or the spousal benefit (50% of the spouse's old-age benefit), whichever is higher.

The expectation is taken over the future values of labor productivity, z' given the processes F_z. The social security benefits $SS(\tilde{e})$, are linked to their realized average annual earnings $\tilde{e}$, which is a state variable in the value function. The average historical earnings $\tilde{e}$ for single household evolve according to

$$\tilde{e}' = [(j-1)\tilde{e} + e]/j$$

Retirees do not work, the Bellman equation for a single retiree's problem is given by

$$V^S(j,k,\tilde{e},g) = \max_{c,k'}[u(c,0) + \beta s_{g,j} V^S(j+1,k',\tilde{e}',g)]$$

subject to

$$(1+\tau_c)c + k' = k + y_S^d(Tr_{ss}(\tilde{e}), rk)$$

2.7 The married household decision problem

Similar to Nishiyama (2010), Kaygusuz (2015), Fehr et al. (2017), married households make collective decision to maximize a joint welfare function with equal weights on the spouses instantaneous utilities. The utility function of married couples, U, depends on joint consumption, c, hours worked by the husband, $n_m \in [0,1]$, and the wife, $n_f \in [0,1]$. The functional form is defined as

$$U(c, n_m, n_f + \phi \mathbf{I}_{g=f,n>0}) = u(c/\eta, n_m) + u(c/\eta, n_f + \phi \mathbf{I}_{g=f,n>0})$$

where η is the equivalence scale in consumption. In addition, married households can choose the income taxation method (filing jointly or separately) in order to minimize their total tax liability in the benchmark economy. The Bellman equation for a working-age married household problem is:

$$V^M(j,k,z_m,z_f,\tilde{e}) = \max_{c,k',n_m,n_f} \left\{ U(c,n_m,n_f + \phi \mathbf{I}_{g=f,n>0}) + \beta \mathbb{E}\left[V^M(j+1,k',z_m',z_f',\tilde{e}') | z_m, z_f \right] \right\}$$

subject to

$$(1+\tau_c)c + k' = k + \max\{y_{joint}^d(y_m + y_f), y_{separate}^d(y_m) + y_{separate}^d(y_f)\}$$

where

$$y_g = w z_g \varepsilon_{g,j} n_g + rk/2, \quad g \in \{m, f\}$$

The average historical earnings $\tilde{e}$ for married household are pooled[5]:

$$\tilde{e}' = [(j-1)\tilde{e} + (e_m + e_f)/2]/j$$

The Bellman equation for a retired couples' problem is given by

$V^M(j,k,\tilde{e}) = \max_{c,k'}[U(c,0,0) + \beta s_{m,j} s_{f,j} V^M(j+1,k',\tilde{e}') + \beta s_{m,j}(1-s_{f,j}) V^S(j+1,k',\tilde{e}',m)$

[5]This simplification implies no social security spousal and survival benefits: the secondary earner receives either own retirement benefit or 50% of the spousal, whichever is higher.

$$+\beta s_{f,j}(1-s_{m,j})V^S(j+1,k',\tilde{e}',f)]$$

subject to

$$(1+\tau_c)c+k' = k+\max\{y^d_{joint}(y_m+y_f), y^d_{separate}(y_m)+y^d_{separate}(y_f)\}$$

2.8 Technology

The consumption goods are produced by a representative firm using aggregate capital K and total effective labor N. Output is given by a Cobb-Douglas production function: $Y = \Psi K^\alpha N^{1-\alpha}$. Capital depreciates at rate δ. Firms maximize profits under perfect competition such that,

$$\max_{K,N}[\Psi K^\alpha N^{1-\alpha} - wN - (r+\delta)K]$$

where α is the capital share in production and Ψ defines a technology parameters. As a result the net marginal product of capital equals the interest rate for capital r and the marginal product of labor equals the wage rate for effective labor w.

2.9 Definition of competitive equilibrium

Let $\omega^M = \{j,k,z_m,z_f,\tilde{e}\} \in \Omega$ be a generic state vector of married households and $\omega^S = \{j,k,z_g,\tilde{e},g\} \in \Omega$ be a generic state vector of single households. The stationary equilibrium of the economy is given by a consumption function, $c^M(\omega^M)$ and $c^S(\omega^S)$, a saving function, $k'^M(\omega^M)$ and $k'^S(\omega^S)$, labor supply, $n_m(\omega^M)$,$n_f(\omega^M)$ and $n^S(\omega^S)$, a value function, $V^M(\omega^M)$ and $V^S(\omega^S)$, a wage rate, $w(\omega)$, and a distribution of married households $\Gamma^M(\omega^M)$ and single households $\Gamma^S(\omega^S)$ over the state space, such that

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

2. Factor prices are given by the following inverse demand equations:

$$r(\Gamma) = \alpha(K/N)^{\alpha-1} - \delta$$
$$w(\Gamma) = (1-\alpha)(K/N)^\alpha$$

3. Factor markets clear

$$K = \int k'^M(\omega^M)d\Gamma^M(\omega^M) + \int k'^S(\omega^S)d\Gamma^S(\omega^S)$$
$$N = \int [z_m\varepsilon_{m,j}n^M_m(\omega^M) + z_f\varepsilon_{f,j}n^M_f(\omega^M)]d\Gamma^M(\omega^M) + \int z_m\varepsilon_{m,j}n^S_m(\omega^S)d\Gamma^S(\omega^S) + \int z_f\varepsilon_{f,j}n^S_f(\omega^S)d\Gamma^S(\omega^S)$$

4. The government budget balances:

$$G + 2\int SS(\tilde{e})d\Gamma^M(\omega^M) + \int SS(\tilde{e})d\Gamma^S(\omega^S) = \tau_s\left[\int c^M(\omega^M)d\Gamma^M(\omega^M) + \int c^S(\omega^S)d\Gamma^S(\omega^S)\right] + \int T(y_m, y_f)d\Gamma^M(\omega^M) + \int T(y)d\Gamma^S(\omega^S)$$

5. $\Gamma(\omega)$ is consistent with the policy functions, and is stationary over time.

2.10 Optimal taxation problem

The benevolent Ramsey government maximizes total welfare of each individual in the economy by choosing the parameters of the tax policy $(\lambda_S, \tau_S, \lambda_{MFJ}, \tau_{MFJ}, \lambda_{MFS}, \tau_{MFS})$ subject to a balanced budget constraint and equilibrium responses by married and single households to the tax policy. However, there are 6 parameters characterizing the tax systems and this is computational infeasible to optimize over six dimensions. Since the main interest of this paper is the optimal progressivity, it is necessary to deal with λ_S, λ_{MFJ} and λ_{MFS} so that the optimization problem is solvable. One possible way to do that is to keep λ_{MFJ}/λ_S and λ_{MFS}/λ_S at the benchmark level, and the value of λ^S is adjusted to balance the budget. For computational simplicity, τ_{MFS} is assumed to be the same as τ_S. Therefore, the set of parameters for optimization is reduced to $\{\lambda_S, \tau_S, \tau_{MFJ}\}$. The policy maker is concerned with the total welfare at the long-run steady state of the economy given by

$$\mathcal{W}^{SS}(\lambda_S, \tau_S, \tau_{MFJ}) = \underbrace{\sum_{i=m,f}\int V^S(j,k,z_i,\tilde{e},i)d\Gamma(j,k,z_i,\tilde{e},i)}_{\text{single households}} + \underbrace{\int V^M(j,k,z_m,z_f,\tilde{e})d\Gamma(j,k,z_m,z_f,\tilde{e})}_{\text{married households}}$$

and the optimal tax code is defined as

$$(\lambda_S^*, \tau_S^*, \tau_{MFJ}^*) = \arg\max \mathcal{W}^{SS}(\lambda_S, \tau_S, \tau_{MFJ})$$

The numerical experiment is done by constructing a grid in the space of progressivity parameters (τ_S, τ_{MFJ}), computing the equilibrium and the associated social welfare value for every grid point and then finding the welfare-maximizing progressivity (τ_S^*, τ_{MFJ}^*).

3 Empirical analysis and calibration

In this section we discuss the functional form assumptions and the parameterization of the model that we employ in our quantitative analysis. We use the state of the U.S. economy in 2000 to determine the model parameters. First of all, I choose a set of parameters based on information that is exogenous to the model. Then, I calibrate the remaining parameters so that, in equilibrium, the model economy is consistent with the targeted moments.

These parameters are listed in Table 1,2 and their corresponding target moments are summarized in Table 3. To reduce computational time, the model period is set to 5 years. The benchmark economy is assumed to be in a steady-state equilibrium.

Table 1: Calibration of the Model: Preset Parameters

Parameter	Description	Value	Source
Demographics			
J	Maximum life span	16	
J_r	Mandatory retirement age	10	
$\{s_m, s_f\}_{J_r}^{J}$	Survival probability		SSA 2000
κ	Share of married households	60.3%	Kuhn & Rios-Rull (2016)
Preferences			
σ_c	Risk aversion	1.5	
σ_l^m, σ_l^f	Frisch elasticity	2.5,1.25	Blundell et al. (2016)
η	Equivalent scale	1.7	Heathcote et al. (2010)
Labor Productivity			
$\{\varepsilon_j^m, \varepsilon_j^f\}_{j=1}^{J_r-1}$	Gender age-efficiency profile		Conesa et al. (2009) Guner & Ventura (2012)
Taxes			
τ_c	Consumption tax rate	5.0%	Kindermann & Krueger (2014)
$[\lambda_S, \tau_S]$	parameter estimates: single households	[0.841,8.0%]	Guner et al. (2014)
$[\lambda_{MFJ}, \tau_{MFJ}]$	parameter estimates: married filing jointly	[0.884,9.2%]	Guner et al. (2014)
Social Security			
b_1, b_2	Replacement thresholds	0.198, 1.195	SSA(2000)
SS^{cap}	maximum social security benefit	0.54	SSA(2000)

Table 2: Calibration of the Model: Jointly Calibrated Parameters

Parameter	Description	Value
β	Annual discount rate	0.972
ϕ	Labor participation cost for women	0.1
θ	Labor disutility	2.3
δ	Depreciation rate of capital stock	6.5%
ψ	Social security benefit adjustment factor	0.63
λ_{MFS}	parameter estimates: married filing separately	0.827

Table 3: Summary of Target Moments

Moment	Source	Data Value	Model Fit
Annual Interest rate	McGrattan & Prescott (2010)	4.1%	4.1%
Female (ages 25–54) participation rate 1996	Bureau of Labor Statistics	75.8%	76%
Mean hours worked	Baris,Markus(2016)	35%	34.4%
K/Y		3.0	3.1
Soc. Sec. Pay / GDP	BEA2000	6.1%	6.0%
Share of couple filing separately	SCF 2001	4.7%	4.7%

3.1 Preferences

Preferences are described by a discount rate, β, the coefficient of relative risk aversion, σ, the Frisch elasticity of labor supply, ϵ, the equivalent scale in consumption η and the disutility of work, θ. β is set to 0.972 so that the equilibrium interest rate is 4.1%. Blundell et al. (2016) reported an estimated Frisch elasticity of 0.68 for males and 0.96 for females. This implies $\epsilon_{male} = 1.47$ and $\epsilon_{female} = 1.04$. θ is calibrated so that at the equilibrium an average household allocates 35% of their time endowment to work. σ is set to 1.5 which is within the range typically used in the literature. Using OECD equivalence scale[6], the equivalent scale in consumption η is set to 1.7.

3.2 Technology

The total factor productivity, Ψ, of the production function is set at 1.55 to normalize the equilibrium wage rate, w, to unity. The capital share of income, α, is set to 0.33. The depreciation rate of the capital stock, δ, is set at 6.5% so that the capital-to-income ratio is 3.1.

3.3 Demographics

Households enter the economy at age 20 (model age 1), retire at age 65 (model age 10) and die with certainty at age 100 (model age 16). The conditional survival rates of male and female retirees at the end of each year of age, $s_{m,j}$ and $s_{f,j}$, are taken from 2000 Period Life Table in Social SecurityAdministration. The survival rates at the end of age 100 are set to be zero. Households are assumed to be either married or single when they enter the economy. The exogenous degree of spousal sorting by educational attainment is taken from Greenwood et al. (2016) who estimated the sorting matrix. The correlation between a husband's and wife's education is 0.519 in the 2005 data. The detail of the sorting matrix is shown in Table 4. Marriages and divorces are abstracted from the model. Married couples become single once their partners pass away after age 65.

Table 4: Assortative Mating

	Wife	
Husband	<College	College
<College	0.545 (0.427)	0.108 (0.226)
College	0.109 (0.227)	0.237 (0.120)

Note: The data values are taken from Greenwood et al. (2016). The number in a cell shows the fraction of all matches that occur in the specified category. The number in parentheses provides the fraction that would occur if matching occurred randomly.

3.4 Income process estimation

To calibrate the components of the transition matrix, I apply the same approach from Bakış et al. (2015) to estimate the transition probabilities in A and F for men and women separately by using panel data on hourly

[6]The OECD scale assigns a weight of 1.0 to the first adult, 0.7 to each additional adult, and 0.5 to each child.

wages from the PSID (1970–2007). The sample is restricted to men and women of ages 25 to 60 who report to be household heads. To decompose the wages into its life cycle and permanent components, we estimate the following specification:

$$\ln w_{\iota t} = \xi_{\iota i} + \Lambda(age_{\iota t}; \Xi) + I_t + \varepsilon_{\iota t}$$

where $\xi_{\iota i}$ denotes the fixed effect for worker ι of generation i. Since fathers and sons may be observed at different points in the life cycle, and possibly at different points of a business cycle, indicators for survey year, I_t, and a quartic polynomial in age, $\Lambda(age_{\iota t}; \Xi)$, are included as control variables.

The permanent component of wages is defined by $f_{\iota i} = \hat{\xi}_{\iota i}$ and the life-cycle component by $a_{\iota t} = \Lambda(age_{\iota t}; \hat{\Xi}) + \hat{\varepsilon}_{\iota t}$, where the first terms captures the deterministic age profile of wages, and the second term captures the transitory shock to the wage rate. The variances of the permanent component for men and women in the data are 0.3 and 0.32 respectively and those of the life-cycle component are 0.14 and 0.18, implying that the fixed worker effects capture 68% and 64% of the total wage variance for men and women respectively. This is in line with the findings in Storesletten et al. (2004) who estimate the share of fixed worker effect to be around 56% for earnings and the estimate from Bakış et al. (2015) is 64%.

The value of states (a_L, a_H) and (f_L, f_H) are calibrated such that the means of $a_{\iota t}$ and $f_{\iota i}$ at the stationary state are zero and the standard deviations of each component match their data counterparts. The resulting states for men are $(f_L, f_H) = (-0.30, 0.99)$ and $(a_L, a_H) = (-0.39, 0.37)$. The resulting states for women are $(f_L, f_H) = (-0.74, 0.43)$ and $(a_L, a_H) = (-0.49, 0.37)$. In addition, gender wage gap is taken into account. I use the age-efficiency profile from Conesa et al. (2009) for male and then calibrate the corresponding age-efficiency profile for female such that the gender wage gap is close to the data reported in Guner & Ventura (2012). After that the first period age-efficiency unit is normalized to be 1. Combined with the estimated average wages $\hat{\xi}_{\iota i}$ and the normalized age-efficiency units, these states imply four possible values for male hourly wages: \$9.2, \$19.7, \$33.5 and \$71.6 and that for female: \$7.8, \$18.2, \$25.2 and \$59.2 in 2000 dollars. The comparison of implied gender wage gap in the model and the data provided by Guner & Ventura (2012) is presented in Figure 2.

The transition matrices of life-cycle component for male and female are below[7]:

$$A_{male} = \begin{bmatrix} 0.70 & 0.30 \\ 0.28 & 0.72 \end{bmatrix}; A_{female} = \begin{bmatrix} 0.77 & 0.23 \\ 0.17 & 0.83 \end{bmatrix}$$

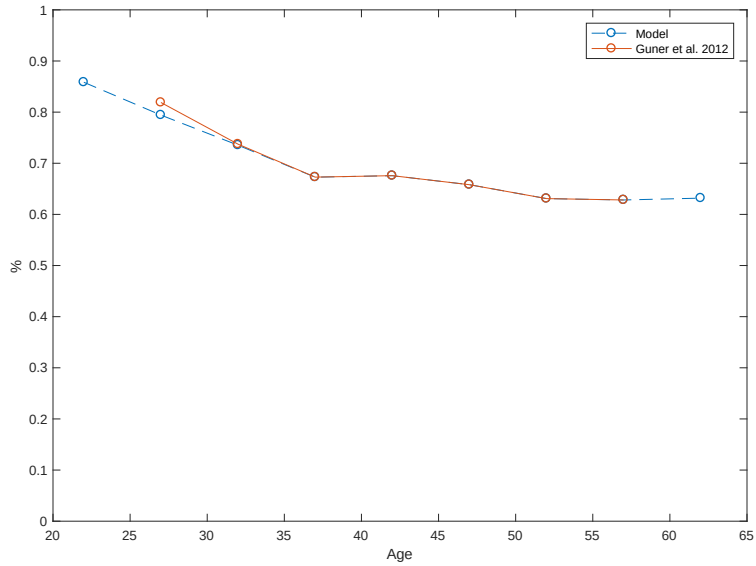
It is not surprising that the transition matrices A are asymmetric and highly persistent. The asymmetry comes from the wage growth over a worker's career. In addition, the productivity shock for female is less fluctuate than that of the male, and hence female has a lower wage growth during the life cycle.

3.5 Tax system

The tax system consists of personal income taxes levied on capital and labor earnings and a sales tax. The tax receipts are used to support exogenous government expenditures and transfers to households. The proportional

[7]The matrix for permanent component is shown in the Appendix. Matrix A is reported at an annual frequency

Figure 2: Gender wage gap



consumption tax rate τ_c is 5%. Personal income taxes are applied to earnings, capital income and pension income, if any. Taxable income for income tax purposes is given by:

$$y_f = wz\varepsilon n \cdot \mathbf{I}_{j<J_r} + SS \cdot \mathbf{I}_{j\geq J_r} + rk$$

Following Benabou (2002) and Heathcote et al. (2017a), disposable (or after-tax) income is obtained by applying a formulation of the current U.S. income tax system, which can be approximated by a log-linear form for income levels:

$$y^d = \lambda y_f^{1-\tau}$$

The power parameter $0 \leq \tau \leq 1$ controls the degree of progressivity of the tax system, while λ controls the level of tax rate. $\tau = 0$ implies a flat tax system. When $\tau = 1$, all income is pooled, and redistributed equally among agents. For $0 < \tau < 1$, the tax system is progressive[8].

This functional form of income tax code provides a good approximation to the actual tax and transfer system in the United States. Guner et al. (2014) use this parametric class of tax function to estimate the parameters λ and τ for married and single households by using data from the Internal Revenue Service 2000 Public Use Tax File[9]. Similar to Bakış et al. (2015), disposable income is defined as earnings minus federal and state income taxes. Therefore, I choose the parameter estimates for the case of when state and local income taxes are included alongside federal income taxes[10].

To capture the fact that there is only 4.7% of married couples choosing to file separately found in SCF 2001, I calibrate the parameter λ^{MFS} for the tax code of married filing separately to match with this stylized fact and assume another parameter τ^{MFS} is the same as that of single households. The reason of calibrating the

[8]The average tax rate is $1 - \lambda y^{-\tau}$, which is increasing in y if $\tau > 0$.

[9]Married households refer to those choosing "married filing jointly", whereas single households include all those filing as single and as head of household.

[10]Guner et al. (2014) reported this paramter values in Online Appendix

parameter λ is that, in the data, the tax schedule of married filing separately has a average tax rate greater than or equal to that of unmarried single for the same amount of income[11]. This feature is in line with my calibrated ratio $\lambda^{MFS}/\lambda^{S} = 0.983$. As the parameter λ controls average tax rate, so larger value of λ means lower average tax rate.

The level of government expenditure, G, is chosen as a residual such that the government budget constraint is balanced in benchmark model, which is 13.3% of the GDP. In the policy experiments, G/Y is kept at the benchmark level.

Table 5: Not Targeted Moments

Moment	Source	Data Value	Model Fit
Variance of log earnings (1970-2002 PSID)	Heathcote et al. 2010	0.68	0.70
Gini coefficient of pre-tax income (1970-2005)	Heathcote et al. 2010	0.39	0.41
Married Female (ages 25–54) participation rate	Guner et al. 2012	69%	68%
Gov. consumption expenditure/GDP	NIPA2000	14%	13.2%
Difference between average income tax rate for top 1% and 99%	Piketty and Saez (2007)	6.8%	8.5%

4 Model Performance

To verify that our benchmark model is reliable for quantitative experiment, in this section I evaluate the model performance along a number of dimensions not targeted by the calibration. At the aggregate level, the model is in line with data. Table 5 summarizes the performance of the benchmark model.

One key feautre determining optimal progressivity of the tax code is female participation in the labor market. It is the first order important that the model captures well the evolution of female labor-force participation over the working period. Figure 3 shows that the model does a good job generating this. In addition to the life-cycle dynamic, the model can also reproduce the aggregate labor-force participation rate of married women accurately although the target for the model is the total participation of single and married women. The match between data and model indicates the model ability to capture the non-trivial labour-force participation decision for married women in my model.

Apart from female labor participation statistics, some other moments statistics are valuable to test the performance. First of all, the income process estimation in my model delivers a close match of variance of log earnings and Gini coefficient of pre-tax income. The close match of income dispersion from different dimensions provides a confidence support to the income process estimation.

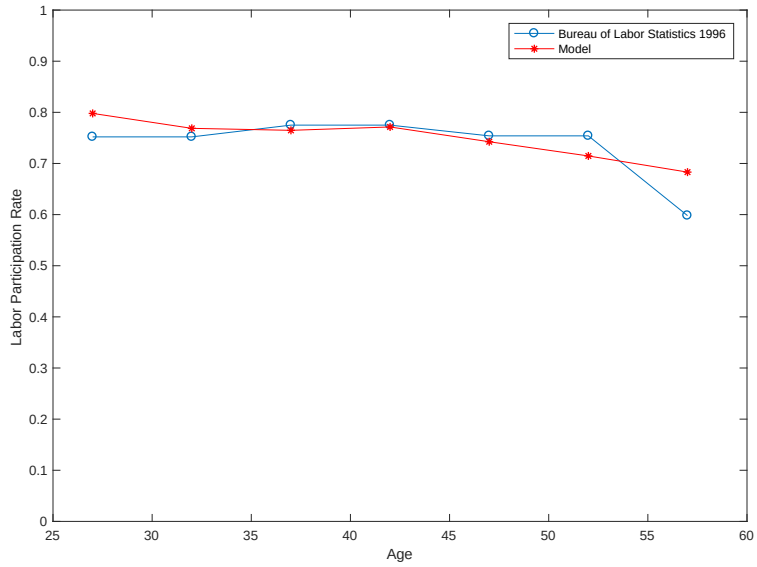
Although the tax parameters are taken from Guner et al. (2014), the implied tax rates and the corresponding residual government expenditure fit with the data well. The difference between average income tax rate for top 1% and 99% illustrate the progressivity of the overall tax system, which is not far from the data.

Overall, the model is consistent with many key facts from U.S. micro data. The test of non-targeted moments

[11] As mentioned in Alesina et al. (2011): With separate taxation, the second earner is effectively taxed at a higher tax rate, relative to that of singles, in systems where the dependent spouse allowance is lost when both family members work or due to other similar family-based measures.

reinforces the reliability of the income process, forces governing female labor supply and the exogenously given tax system. As a result, it is confident to employ it to assess the optimal progressivity of the income tax code.

Figure 3: Married females labor force participation rate by age



5 The optimal tax policy

The government maximizes the total welfare of each individual in the economy by choosing the progressivity parameters subject to a balanced budget constraint and equilibrium responses by single and married households to the tax policy. The findings suggest that the optimal tax code in the long run is more progressive than the current U.S. tax system for both single and married households. The optimal progressivity for single and married households are $\tau_S = 0.17$ and $\tau_{joint} = 0.12$, respectively. The average (by population) welfare gain from increasing progressivity from the current value $\tau_S^{US} = 0.08$ and $\tau_{joint}^{US} = 0.092$ to the optimal is equivalent to 1.48% of lifetime consumption.

Table 6 and 7 compare the average and marginal tax rates between the optimal tax system and the estimated U.S. system. Under a more progressive tax system, the marginal tax rates and average tax rates are considerably higher for households in the top of the income distribution while they are lower and even negative for households

Table 6: Average tax rates across income groups

Average tax rates (%)	Income Quintiles				
	1st	2nd	3rd	4th	5th
Benchmark					
Single	9.0	13.0	16.7	19.3	23.6
Married	5.9	8.7	12.4	16.1	22.3
Optimal					
Single	-0.8	8.5	16.8	22.2	31.2
Married	-5.2	1.0	7.7	15.8	24.4

Table 7: Marginal tax rates across income groups

Marginal tax rates (%)	Income Quintiles				
	1st	2nd	3rd	4th	5th
Benchmark					
Single	15.6	19.9	23.2	25.7	29.2
Married	14.5	17.0	20.3	23.8	28.4
Optimal					
Single	15.0	23.9	30.7	35.3	42.1
Married	11.2	15.6	22.0	27.0	32.5

in the bottom of the income distribution, as compared to the benchmark system.

It is instructive to explore the economic forces underlying the results regarding the optimal tax system, I compare the steady state of the benchmark economy calibrated to the U.S. tax policy with that obtained under the optimal tax system in Table 8.[12] An increase in the progressivity of the tax policy reduces the after-tax return to labor and capital. More redistribution also provides better protection against income risk but reduces precautionary saving motives which decreases total savings in the economy. In particular to the high-income group, the negative income effect generated by higher taxes outweigh the positive income effect of higher equilibrium interest rate, and therefore the net return is lower which further discourages savings. Overall, the supply of capital decreases by almost 8%.

The lower capital stock has two implications for labor. First, it reduces the demand for labor, and decreases the wage rate, despite the upward pressure created by the decrease in the labor supply. Second, lower wealth has a positive income effect on labor supply, limiting the decrease in labor input, and pushing the wage rate further down. With a lower stock of capital and decreased labor input, output decreases. The optimal tax system leads to a 3.99% decrease in output, which translates to a 3.17% decrease in consumption. The fall in welfare due to lower average consumption is mitigated by the 1.22% increase in average leisure.

Because of the concavity of the individual utility function, the social planner with utilitarian welfare criterion favors redistribution by using a more progressive tax system to counteract inequality in initial conditions and substitute for imperfect private insurance against idiosyncratic earnings risk. Despite the reduced labor supply and capital accumulation, the change of equilibrium prices improves social welfare substantially. To illustrate this, I evaluate the magnitude of general equilibrium effect to steady-state welfare gains by computing a new steady state with the optimal tax system but fixing wages and returns to capital at their benchmark level. Column 4 of Table 8 presents the results from this exercise. This experiment disentangles the welfare gains into one part that is due to higher returns to capital, and a part that is due to better insurance against income shocks and more equitable distribution. The first part is taken away whereas the latter part can be identified. The equilibrium price adjustments, especially the interest rate, improve the welfare of steady state substantially in terms of a 1.2% increase in lifetime consumption. A more progressive tax system reduces the tax rate on lower income individuals, and therefore it raises the net returns to savings, which encourages saving for the low-income

[12] For total labor supply N, capital stock K, GDP Y, wages w, consumption C and level of government expenditure G we report percentage deviations from the values for the benchmark economy.

Table 8: Optimal tax system: steady-state comparison

	U.S.	Optimal	Flat Tax	Partial Equilibrium
Progressivity (τ_S, τ_{joint})	[8%,9.2%]	[17%,12%]	[0,0]	[17%,12%]
Average tax rate $(1-\lambda_s, 1-\lambda_M)$	[0.159,0.116]	[0.148,0.104]	[0.214,0.174]	[0.149,0.105]
Interest rate r	4.12%	4.49%	3.67%	4.12%
Wages w	1.04	-2%	2.9%	0%
Married female labor participation	68.2%	69.5%	68.6%	69.6%
Total labor supply N	253.4	-2.01%	3%	-1.5%
Capital stock K	255.2	-7.92%	11.4%	-11.9%
GDP Y	393.7	-3.99%	5.7%	-5.1%
Aggregate consumption C	16.7	-3.17%	4.2%	-3%
Level of gov. expenditure G	52.2	-4.02%	5.7%	-5.2%
Tax revenue share (single,couple)	[0.26,0.74]	[0.255,0.745]	[0.3,0.7]	[0.254,0.746]
% Couples choosing filing separately	4.68%	42.3%	0.0	42.3%
Social Security payment/GDP	6.0%	5.9%	5.99%	6.15%
Gini coef. for pre-tax earnings	0.424	0.430	0.421	0.427
Gini coef. for pre-tax income	0.411	0.415	0.411	0.415
Gini coef. for after-tax income	0.404	0.384	0.442	0.388
Gini coef. for wealth	0.569	0.561	0.592	0.571
Gini coef. for consumption	0.322	0.313	0.348	0.313
Welfare gain in % lifetime consumption	0	1.48%	-3.32%	0.28%

group. As a result, wealth inequality is lower.

Pre-tax income inequality is slightly higher under progressive taxes due to the change in the equilibrium prices. The rise in the interest rate favors the wealthy groups, especially for those with a larger portion of capital income. While the decline in the wage rate harms workers who depend heavily on labor income. Nonetheless, the economy with progressive taxes features lower wealth inequality along with a decrease in the inequality of after-tax income disposable for consumption. The Gini coefficient for wealth inequality drops 1.41%, and that for after-tax income drops 4.95%. The impact of falling after-tax income inequality on consumption, however, is limited. The Gini coefficient for consumption inequality drops 2.8%, about half of the fall in disposable income inequality. This is due, in large part, to the availability of self-insurance through precautionary savings. Note that the Gini coefficient for consumption is lower under the new tax system (both with equilibrium and fixed prices) than the benchmark tax system, which indicates more insurance in the optimal, compared to the benchmark system. The optimal economy provides better protection to the poor groups through lower tax rates and transfers with the objective of promoting capital accumulation for the bottom part of wealth distribution. While the wealthy group is subject to higher tax rates which reduce the return of savings. As a consequence, the decreased capital accumulation for the wealthy group and the increased capital accumulation for the poor group make the wealth and consumption distributions less disperse. In order to demonstrate the important role of insurance and redistribution effect in welfare improvement, it is necessary to compare the welfare level between a flat tax system and the optimal progressive system, which is represented in column 4 of Table 8. The comparison reveals the presence of a strong social desire for insurance redistribution. Even though GDP and aggregate consumptions are roughly 5.7% and 11.4% higher in a purely proportional system compared to the benchmark, social welfare is substantially lower under the flat tax system. This is because a purely proportional

system does not provide insurance against ex-ante heterogeneity and earnings uncertainty.

These experiments reveal that two features are key for the optimality of a tax system when only steady-state outcomes are considered. First of all, the effect of taxes on saving, and the resulting changes in equilibrium prices. These features are absent in settings where there is no effect of capital accumulation on returns to saving or general equilibrium effect (as in Gayle & Shephard (2016)). Second, this means that from the perspective of a couple, self-insurance against income risk is more attractive than insurance provided by the government, so that married households prefer a situation with less progressivity tax system. In contrast, single households have a hard time self-insuring against the income risk, so that they would rather rely on governmental insurance schemes, and hence a more redistributive tax system.

6 Decomposition of optimal progressivity

One of the main objectives of this paper is to study how the presence of married households and the option of separate filing affect tax progressivity in the quantitative model. Table 9 shows a decomposition exercise quantifying the contributions of different key features of family structure and tax treatment for married households to the optimal progressivity. To establish a useful benchmark to compare with, I start to compare the optimal progressivity with a model having single-male households only and then each component is introduced sequentially, starting with gender and marital status (column 2), assortative marriage (column 3), different elasticity of labor supply (ELS) and labor participation cost (LPC) (column 4), then followed by having all features together (column 5), and finally the option of filing separately (column 6).

I find that neglecting the gender and marital status in the model results in a heavily suboptimal level of tax progressivity for singles. Column 1 of Table 9 shows that the welfare of an economy with only single-male households is maximized at $\tau_S = 0.16$. Adding the gender and marital status components (column 2) pushes toward a more progressive system, and the optimal progressivity for singles τ_S increases to 0.21 and the optimal progressivity for couples τ_{joint} is 0.18. Note that the key features of family structures such as assortative matching and some features of female labor supply are absent in that economy. The main reason of higher progressivity is the increased inequality once females and married couples are introduced. First of all, females have, on average, lower income than male counterparts. Therefore, inequality of an economy having females should be higher, which pushes up progressivity for stronger redistribution. Second, married households enjoy economies of scale in consumption and also they have higher household income than single household. These two features increase consumption inequality of the whole economy, which results in a more progressive tax system. In addition, the government optimally splits the share of tax revenue from single and married households into 20/80 roughly. The high income married household is the main source of tax revenue so the government should optimally have a less progressive tax schedule on married households compared to singles[13]. Compared to the model with only single individual, the reduced tax revenue from single households allows a further rise of progressivity of singles in the model with couples.

[13]Heathcote et al. (2017a), Holter et al. (2017) show that the ease of raising government tax revenue decreases with tax progressivity.

Table 9: Decomposition of optimal progressivity

	(1)	(2)	(3)	(4)	(5)	(6)
	single male	+couples,females	+couples,females +assortative matching	+couples,females +Different ELS,LPC	+couples,females +assortative matching +Different ELS,LPC	+couples,females +assortative mating +Different ELS,LPC +tax filing separately
	Optimal	Optimal	Optimal	Optimal	Optimal	Benchmark optimal
Progressivity (τ_s, τ_{joint})	[0.16,0.16]	[0.21,0.18]	[0.21,0.20]	[0.19,0.16]	[0.21,0.17]	[0.17,0.12]
Average tax rate $(1-\lambda_S, 1-\lambda_{joint})$	[0.148,0.148]	[0.109,0.063]	[0.098,0.052]	[0.118,0.073]	[0.112,0.066]	[0.148,0.104]
Interest rate r	4.59%	4.81%	4.79%	4.57%	4.7%	4.48%
Wages w	1.014	1.002	1.003	1.015	1.008	1.02
Average hours worked per worker	33.1%	33.5%	33.9%	34.2%	32.8%	33.6%
Married female labor participation	n.a	100%	100%	66.4%	66.6%	69.5%
Total labor supply N	242.2	239.9	234.2	261.3	244.2	248.3
Capital stock K	225.1	215.3	210.5	243.6	223.3	235.0
GDP Y	366.4	358.8	350.5	395.7	367.5	378.0
Aggregate consumption C	10.4	15.6	15.2	17.0	15.8	16.17
Level of gov. expenditure G	45.3	46.5	45.4	51.7	48.7	50.1
Tax revenue share (single,couple)	[1.0,0.0]	[0.214,0.786]	[0.214,0.786]	[0.215,0.785]	[0.217,0.783]	[0.255,0.745]
% Couples choosing filing separately	0.0	0.0	0.0	0.0	0.0	42.3%[a]
Social Security payment/GDP	6.48%	6.1%	5.98%	6.02%	5.9%	5.9%
Gini coef. for pre-tax earnings	0.419	0.403	0.412	0.421	0.431	0.430
Gini coef. for pre-tax income	0.4069	0.388	0.396	0.406	0.414	0.415
Gini coef. for after-tax income	0.3592	0.347	0.344	0.368	0.368	0.384
Gini coef. for wealth	0.550	0.529	0.524	0.548	0.548	0.561
Gini coef. for consumption	0.266	0.280	0.280	0.297	0.299	0.313
Welfare gain in % lifetime consumption	2.03%	1.84%	2.48%	1.75%	2.12%	1.48%

[a] 20.3% of welfare gain from filing separately

Knowing that gender and marital status are quantitatively important to the optimal progressivity, it is imperative to explore a quantitative question further, whether, and to what extent, assortative marriage and features of female labor supply determine tax progressivity in a calibrated life-cycle model.

The concern for a more dispersed income distribution caused by assortative marriage pushes up the progressivity for married households. A more progressivity tax system is required to counteract the more skewed educational attainment distribution among married households driven by the assortative matching.

Instead, if only adding a higher elasticity of female labor supply in addition to a higher labor participation cost, the progressivity goes down. The intuition is that, in the case of filing jointly, the marginal tax rate is the same for both members of the family, which results in high tax rates on secondary earners, most of them are female. When a second earner considers entering the labor market, the first dollar of her earned income is taxed at primary earner's current marginal rate. As a consequence, lower tax progressivity is required to reduce distortions to family labor supply because of the higher elasticity of female labor supply.

When both assortative marriage and female labor supply features are put together, the progressivity for married households is in-between of the case (3) and (4) while the progressivity for single households remains unchanged. From the perspective of adding assortative mating to the case (4), there will be more households with two high earning members, the distortion of the high marginal tax rate on second earner's labor participation decision is alleviated since her income level is similar to the primary one. Moreover, the income inequality is increased, and hence progressivity is higher relative to the case (4). On the other hand, adding female labor participation cost to the case (3), the effect of assortative marriage on income inequality is limited by the decline of labor supply from high-earning female[14]. Together with the larger distortion of female labor supply induced from higher elasticity, optimal progressivity for married households is further pushed down. The overall effects make the optimal progressivity for married households in-between of case (3) and (4). The features of married households affect the progressivity for singles through the change in the equilibrium prices. The increased returns to saving and the decreased wage rate exaggerate the income inequality within single households. The increased returns to saving favors the wealthy singles who have more capital income while the decreased wage rate harms the poor singles who have more labor income. Knowing that a higher income inequality translates to a higher consumption inequality, the inequality-averse social planner needs to adopt a more progressive tax system to internalize the externality of married households' responses.

Finally, I allow married households to choose either be taxed with joint income or separate income so that we are back in our benchmark scenario. A detailed decomposition shows that the choice of tax filing separately substantially reduces the optimal progressivity for couples. The existing U.S. income tax schedule for married couples is non-marriage-neutral. Couples with spouses whose individual incomes are similar tend to pay higher taxes when married than their combined tax liabilities as single filers (marriage tax), while those whose incomes are farther apart pay less (marriage subsidy). The option of filing separately provides an alternative for married households to reduce the marriage tax. In the optimal benchmark scenario (column 6), 42.3% of married households benefit from taxing separately which contributes 20.3% of welfare improvement in the optimal tax

[14] Greenwood et al. (2014) illustrated the fact that for positive assortative matching to have an impact on income inequality married females must work.

system due to the efficiency gains from higher labor supply and consumption. In addition, looking at the income ratio of the second to the first earner of those taxing separately, 56% of them have household income ratio less than half. The intuitive explanation is that those low-income second earners are more elastic to the change in income and they find it optimal to reduce the marginal tax rate by choosing separate filing. In other words, the option of filing separately reduces the cost of labor participation for second earners, and therefore the married female labor participation rate increases by 2.8%. Not only are the married households with low-income ratio benefitted, but also those with a high-income ratio. 90% of them decide to file separately in order to reduce the marriage tax. Since couples face idiosyncratic wage shocks together and hence their income ratio varies every period. The option of filing status provides flexibility for couples to better insure the joint-income shocks by minimizing their tax burdens. Such an option limits the need for redistributive public insurance for couples. In addition, not only can married households minimize their tax liability which reduces the tax revenue, the second earners are also encouraged to participate in the labor market which results in higher output. Given the ratio of government expenditure to GDP is kept at the benchmark level, higher output leads to higher government expenditure. Together with reduced tax revenue and higher government expenditure, the planner internalizes that a less progressive system encourages labor supply, and makes it easier to finance expenditure.

7 Conclusion

This paper shows that the optimal tax system is significantly more progressive than the system currently in place in the United States by using a life cycle general equilibrium model with both single and married households under a utilitarian social welfare function. In addition, a detailed decomposition highlights the role of gender and marital status in the determination of an optimal redistribution system. Not considering the presence of females and married households in the model result in a heavily suboptimal level of tax progressivity. This quantitative exercise highlights the fact that macroeconomists should not ignore women and marriage in setting up structural models to study optimal tax policy[15]. The heterogeneity of households increases substantially with the introduction of gender and marital status and the corresponding features of couples such as assortative matching, differences in elasticity of labor supply and labor participation cost for female. A more progressive tax system is optimal in the sense that the poor benefit from higher returns to saving induced by lower tax rates for the low-income group. Although the rich save less due to the increased tax rates, the resulting increase in interest rate can improve social welfare by promoting the savings motives for the bottom group. A highly progressive tax system is preferred because the utilitarian social welfare function weighs utility gains of raising social insurance for poor agents more heavily than utility loss of distortions to labor supply and savings for the rich, overall steady state welfare under the more progressive system is higher than that of the benchmark.

The sharp disparity of optimal progressivity between single and married households illustrates the important role of self-insurance in marriage. Providing more social insurance for singles than couples is optimal. An interpretation of this finding is that government should derive welfare gains from married households by reducing

[15]Borella et al. (2017) shows that modeling gender and marriage explicitly would yield the best calibration results in terms of matching the economic aggregates.

distortions to couples' decision making with a less progressivity system. In opposite, the singles are more vulnerable to risks, and the government should, therefore, provide more social insurance for them.

Apart from the key features of the family structure, the option of separate filing for couples is quantitatively important to the degree of optimal progressivity. This option provides flexibility for couples to better insure the joint-income shocks and hence it limits the need for redistributive public insurance for couples. Furthermore, this tax treatment feature results in putting a burden on the ease of financing government expenditure by decreasing the tax revenue collected from couples and increasing the amount of expenditure. Literature studying policy reforms related to a family should pay attention to this key element.

The life cycle structure of the general equilibrium model illustrates the quantitative importance of the equilibrium price adjustments, especially the interest rate, which improves welfare at the steady state substantially in terms of 1.2% increase in lifetime consumption. This appealing result sheds light on the main drawback of using a static model for studying fiscal policy.

References

Alesina, A., Ichino, A. & Karabarbounis, L. (2011), 'Gender-based taxation and the division of family chores', *American Economic Journal: Economic Policy* **3**(2), 1–40.

Bakış, O., Kaymak, B. & Poschke, M. (2015), 'Transitional dynamics and the optimal progressivity of income redistribution', *Review of Economic Dynamics* **18**(3), 679–693.

Benabou, R. (2000), 'Unequal societies: Income distribution and the social contract', *American Economic Review* **90**(1), 96–129.

Benabou, R. (2002), 'Tax and education policy in a heterogeneous agent economy: What levels of redistribution maximize growth and efficiency?', *Econometrica* **70**(2), 481–517.

Blundell, R. & MaCurdy, T. (1999), Labor supply: A review of alternative approaches, *in* 'Handbook of labor economics', Vol. 3, Elsevier, pp. 1559–1695.

Blundell, R., Pistaferri, L. & Itay, S. (2016), 'Consumption inequality and family labor supply', *The American Economic Review* **106**(2), 387–435.

Borella, M., Nardi, M. & Yang, F. (2017), 'The aggregate implications of gender and marriage', *Journal of the Economics of Ageing* .

Conesa, J. C., Kitao, S. & Krueger, D. (2009), 'Taxing capital? not a bad idea after all!', *American Economic Review* **99**(1), 25–48.

Conesa, J. & Krueger, D. (2006), 'On the optimal progressivity of the income tax code', *Journal of Monetary Economics* **53**(7), 1425–1450.

Fehr, H., Kallweit, M. & Kindermann, F. (2017), 'Families and social security', *European Economic Review* **91**(November 2015), 30–56.

Frankel, A. (2014), 'Taxation of couples under assortative mating', **6**(3), 155–77.

Gayle, G. & Shephard, A. (2016), 'Optimal taxation, marriage, home production, and family labor supply'.

Greenwood, J., Guner, N., Kocharkov, G. & Santos, C. (2014), 'Marry your like: Assortative mating and income inequality', *American Economic Reviews: Papers & Proceedings* **104**(5), 348–353.

Greenwood, J., Guner, N., Kocharkov, G. & Santos, C. (2016), 'Technology and the changing family: A unified model of marriage, divorce, educational attainment, and married female labor-force participation', *American Economic Journal: Macroeconomics* **8**(1), 1–41.

Guner, N., Kaygusuz, R. & Ventura, G. (2014), 'Income taxation of U.S. households: Facts and parametric estimates', *Review of Economic Dynamics* **17**(4), 559–581.

Guner, N. & Ventura, G. (2012), 'Taxation and household labour supply', *Rev Econ Stud* **79**(December 2011), 1113–1149.

Heathcote, J., Perri, F. & Violante, G. L. (2010), 'Unequal we stand: An empirical analysis of economic inequality in the united states, 1967 – 2006', *Review of Economic Dynamics* **13**(1), 15–51.

Heathcote, J., Storesletten, K. & Violante, G. L. (2017a), 'Optimal tax progressivity: An analytical framework', *The Quarterly Journal of Economics* **132**(4), 1693–1754.

Heathcote, J., Storesletten, K., Violante, G. L. et al. (2017b), 'Optimal progressivity with age-dependent taxation', *URL: http://violante. mycpanel. princeton. edu/Workingpapers/hsv_ agedep_ tax_ v17_ JH_ Joan. pdf* .

Heathcote, J. & Tsujiyama, H. (2015), 'Optimal income taxation: Mirrlees meets ramsey'.

Holter, H., Krueger, D. & Stepanchuk, S. (2017), 'How do tax progressivity and household heterogeneity affect laffer curves'.

Kaygusuz, R. (2015), 'Social security and two-earner households', *Journal of Economic Dynamics and Control* **59**, 163–178.

Kaymak, B. & Poschke, M. (2016), 'The evolution of wealth inequality over half a century: The role of taxes, transfers and technology', *Journal of Monetary Economics* **77**, 1–25.

Keane, M. P. (2011), 'Labor supply and taxes: A survey', *Journal of Economic Literature* **49**(4), 961–1075.

Kindermann, F. & Krueger, D. (2014), 'High marginal tax rates on the top 1%?'.

Kleven, H., Kreiner, C. & Saez, E. (2009), 'The optimal income taxation of couples', *Econometrica* **77**(2), 537–560.

Kuhn, M. & Rios-Rull, J.-V. (2016), '2013 update on the us earnings, income, and wealth distributional facts: A view from macroeconomics', *Quarterly Review, Federal Reserve Bank of Minneapolis, April* pp. 1–75.

McGrattan, E. R. & Prescott, E. C. (2010), 'Unmeasured investment and the puzzling us boom in the 1990s', *American Economic Journal: Macroeconomics* **2**(4), 88–123.

Nishiyama, S. (2010), 'The joint labor supply decision of married couples and the social security pension system'.

Ramsey, F. P. (1927), 'A contribution to the theory of taxation', *The Economic Journal* **37**(145), 47–61.