Essays in Inequality and Public Economics

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Most importantly, I want to thank my family and Michelle for their love and support. I dedicate this work to them.

Dedication

To my family and Michelle.

My lovely grandpa and grandma, you will never read this, but know that you help me all these years.

Abstract

This dissertation consists of three chapters which contribute to quantitative and theoretical understanding of inequality and associated public policies.

The first essay studies how different should income taxation be across singles and couples. I answer this question using a general equilibrium overlapping generations model that incorporates single and married households, intensive and extensive margins of labor supply, human capital accumulation, and uninsurable idiosyncratic labor productivity risk. The degree of tax progressivity is allowed to vary with marital status. I parameterize the model to match the U.S. economy and find that couples should be taxed less progressively than singles. Relative to the actual U.S. tax system, the optimal reform reduces progressivity for couples and increases it for singles. The key determinants of optimal policy for couples relative to singles include the detrimental effects of joint taxation and progressivity on labor supply and human capital accumulation of married secondary earners, the degree of assortative mating, and within-household insurance through responses of spousal labor supply. I conclude that explicitly modeling couples and accounting for the extensive margin of labor supply and human capital accumulation is qualitatively and quantitatively important for the optimal policy design.

In the second essay, I develop a framework for assessing the welfare effects of labor income tax changes on married couples. I build a static model of couples' labor supply that features both intensive and extensive margins and derive a tractable expression that delivers a transparent understanding of how labor supply responses, policy parameters, and income distribution affect the reform-induced welfare gains. Using this formula, I conduct a comparative welfare analysis of four tax reforms implemented in the United States over the last four decades, namely the Tax Reform Act of 1986, the Omnibus Budget Reconciliation Act of 1993, the Economic Growth and Tax Relief Reconciliation Act of 2001, and the Tax Cuts and Jobs Act of 2017. I find that these reforms created welfare gains ranging from -0.16% to 0.62% of aggregate labor income. A sizable part of the gains is generated by the labor force participation responses of women. Despite three reforms resulting in aggregate welfare gains, I show that each reform created winners and losers. Furthermore, I

uncover two patterns in the relationship between welfare gains and couples' labor income. In particular, the reforms of 1986 and 2017 display a monotonically increasing relationship, while the other two reforms demonstrate a U-shaped pattern. Finally, I characterize the bias in welfare gains resulting from the assumption about a linear tax function. I consider a reform that changes tax progressivity and show that the linearization bias is given by the ratio between the tax progressivity parameter and the inverse elasticity of taxable income. Quantitatively, it means that linearization overestimates the welfare effects of the U.S. tax reforms by 3.6-18.1%.

The third essay studies the policies that are aimed at mitigating COVID-19 transmission. Most economic papers that explore the effects of COVID-19 assume that recovered individuals have a fully protected immunity. In 2020, there was no definite answer to whether people who recover from COVID-19 could be reinfected with the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). In the absence of a clear answer about the risk of reinfection, it is instructive to consider the possible scenarios. To study the epidemiological dynamics with the possibility of reinfection, I use a Susceptible-Exposed-Infectious-Resistant-Susceptible model with the time-varying transmission rate. I consider three different ways of modeling reinfection. The crucial feature of this study is that I explore both the difference between the reinfection and no-reinfection scenarios and how the mitigation measures affect this difference. The principal results are the following. First, the dynamics of the reinfection and no-reinfection scenarios are indistinguishable before the infection peak. Second, the mitigation measures delay not only the infection peak, but also the moment when the difference between the reinfection and no-reinfection scenarios becomes prominent. These results are robust to various modeling assumptions.

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Chapter 1

Optimal Income Taxation of Singles and Couples

1.1 Introduction

How different should income taxation be across singles and couples? The answer to this question is of crucial importance for both academic economists and policymakers. In this paper, I focus on a particular aspect of income taxation, that is progressivity, which I define as 1 minus the average elasticity of post-tax/transfer income to pre-tax/transfer income. For example, in the Unites States, progressivity for single individuals is around 12%, meaning that, on average across the income distribution, a 10% increase in pre-tax/transfer income results in a 8.8% increase in post-tax/transfer income. In Figure 1.1, I report tax progressivity for singles and couples in a number of developed countries. The key takeaway from the figure is that there is considerable variation in progressivity of the tax code for singles and couples.[1] In the United States (and in some other countries), progressivity for singles and couples is roughly equal; however, for a majority of countries progressivity for couples is lower than for singles. This evidence raises, first, the question of what is the rationale for taxing couples differently from singles, and, second, whether any given country can improve welfare of its citizens by changing how it taxes couples relative to singles.

This paper focuses on three determinants of taxation of couples relative to singles. First, it considers the well-documented feature that the combination of joint taxation of couples and high progressivity can have a detrimental effect on labor supply and human capital accumulation of the secondary earner in a dual-earner couple (Eissa and Hoynes, 2004; Bick and Fuchs-Schündeln, 2017b; Borella et al., 2022). This feature, ceteris paribus,

[1] In Figure A.1, I also compare average personal income tax rates for singles and married couples in OECD countries. A sizable fraction of observations is located off the 45-degree line.

will favor lower progressivity for couples. Second, it considers the possibility of within-household insurance through responses of spousal labor supply in couples (Attanasio et al., 2005; Blundell et al., 2016a; Wu and Krueger, 2021). The presence of this private insurance device reduces the desired degree of public insurance in the form of tax progressivity. This feature also calls for lower progressivity for couples. Finally, it considers the possibility of positive assortative mating, that is that similarly educated people are more likely to marry each other, which has been highlighted as one of the driving forces of between-household inequality (Fernandez et al., 2005; Eika et al., 2019). This feature will call for higher progressivity for couples.

To consider all these features in a unified framework, this paper develops a general equilibrium overlapping generations model that incorporates single and positively assorted married households facing uninsurable idiosyncratic labor productivity risk, intensive and extensive margins of labor supply, and human capital accumulation. I parameterize the model using the Method of Simulated Moments and data for the United States from the Current Population Survey (CPS) and the Panel Study of Income Dynamics (PSID). The model matches the patterns from the data remarkably well. In particular, it generates the Frisch elasticities of labor supply that are consistent with empirical studies. Having checked the validity of the model, I quantitatively characterize the optimal tax progressivity, separately for single and married households. To find the optimal tax schedule, I maximize the welfare of newborn households at the new steady state.

My first finding is that tax progressivity in the United States should be lower for married couples than for singles. Under the optimal tax schedule, the average elasticity of post-tax/transfer income to pre-tax/transfer income for couples is 4.3 p.p. higher than one for singles. Furthermore, the optimal tax reform increases this elasticity by 3.9 p.p. for married couples and reduces it by 2.6 p.p. for singles relative to the actual U.S. tax system. Under the optimal policy, married women's employment goes up by 2.6 p.p. (from 69.2% to 71.8%). Replacing the actual tax system with the optimal one would generate an aggregate welfare gain of about 1.3% in consumption-equivalent terms.

The model also suggests that there exist welfare-improving reforms that replace the actual U.S. income tax schedule in a revenue-neutral fashion, so that the schedule for one

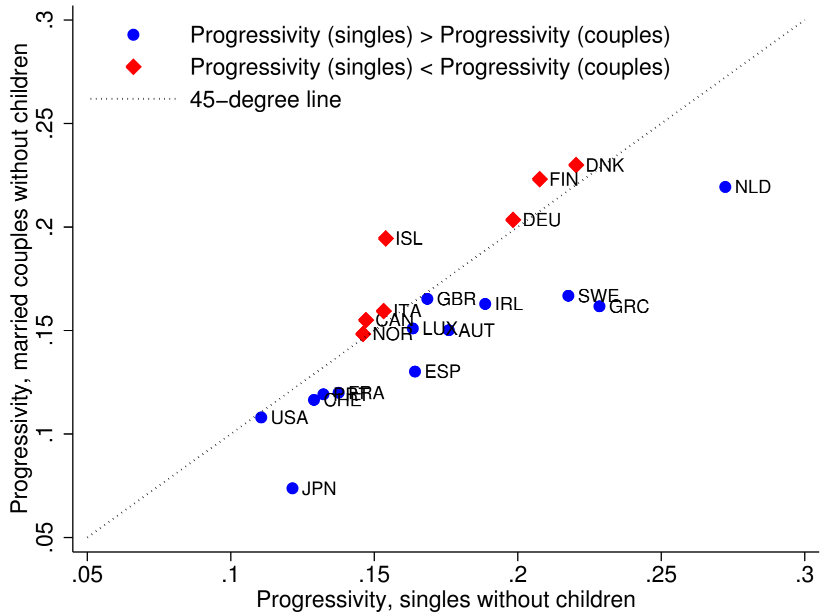


Figure 1.1: Tax Progressivity for Singles and Married Couples by Country

Notes: Progressivity is defined as 1 minus the average elasticity of post-tax/transfer income to pre-tax/transfer income. The dotted line is a 45-degree line. The estimates are from Holter et al. (2019) who use the OECD Tax-Benefit calculator for the period of 2000-2007. For consistency, I consider childless singles and married couples.

group (e.g., singles) remains at the U.S. benchmark level while the schedule for the other group (e.g., couples) is changed. To separate the effects of changes in tax progressivity and average tax rates, I also consider a reform when the government varies the degree of progressivity but keeps the average tax rates at the status-quo level. I find that my main results still hold under this policy rule.

I consider several extensions of the baseline model and show that my main findings carry over into the other environments. First, I relax the assumption that individuals do not change their marital status over the life cycle. Second, I allow the idiosyncratic labor productivity shocks of spouses to be correlated. Finally, I consider a version of the model where married couples can choose between joint and separate filing.

To the best of my knowledge, this work is the first one that addresses the question of optimal taxation of singles and married couples in a unified general equilibrium framework with rich heterogeneity and human capital. I conclude that explicitly modeling couples and accounting for the extensive margin of labor supply and human capital accumulation is qualitatively as well as quantitatively important for the optimal policy design.

This research contributes to several strands of literature. First, it is related to the Ramsey-style papers that study the optimal income taxation in heterogeneous-agent models with incomplete markets (Conesa and Krueger, 2006; Conesa et al., 2009).[2] While most of the papers in this literature abstract from heterogeneity in marital status and gender, Keane (2011) emphasizes the importance of accounting for both of them in studying the relationship between tax and transfer policy and labor supply responses.[3] In this vein, my work is related to the papers that study income taxation of couples. Influential existing studies include Bar and Leukhina (2009), Kleven et al. (2009), Immervoll et al. (2011), Guner et al. (2012a), Frankel (2014), Gayle and Shephard (2019), and Bronson and Mazzocco (2021). Kleven et al. (2009) consider a static unitary model of couples where the primary earners choose labor supply at the intensive margin and the secondary earners choose whether to work or not. Gayle and Shephard (2019), using a static model, study the role of marriage market in shaping the optimal income tax schedule. These two papers suggest that the optimal tax schedule is characterized by negative jointness, i.e. marginal tax rates should be lower for individuals with high-earning spouses. In Bar and Leukhina (2009) and Immervoll et al. (2011), spouses make labor supply decisions at the extensive margin, but do not choose hours.

My work also adds to the literature on tagging pioneered by Akerlof (1978), who suggests that conditioning taxes on personal characteristics can improve redistributive taxation (Cremer et al., 2010). More recently, this idea was discussed in the context of age-dependent taxation (Weinzierl, 2011; Heathcote et al., 2020), gender-based taxation (Alesina et al., 2011; Guner et al., 2012b), and asset-based taxation (Karabarbounis, 2016).

Next, this paper belongs to studies that emphasize the role of females and their labor supply as well as families in studying inequality and macroeconomic policies (Doepke and Tertilt, 2016). Eissa and Liebman (1996) and Eissa and Hoynes (2004) find that the Earned

[2] Stantcheva (2020) provides an excellent discussion of widespread approaches in the dynamic taxation literature. These include the parametric Ramsey, the Mirrlees, and the sufficient statistics approaches.

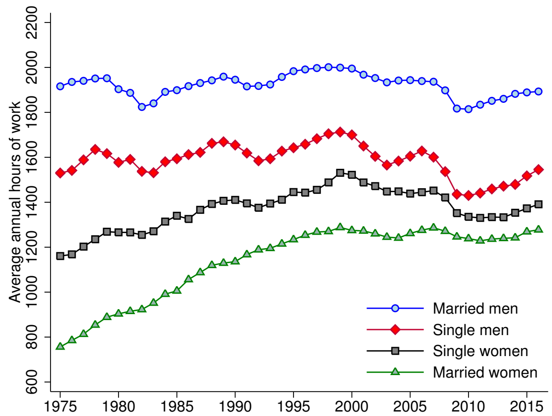
[3] Borella et al. (2018) claim that even macroeconomists not interested in heterogeneity in marital status and gender per se should start taking them into account in the context of quantitative structural models because it would yield better results in terms of matching the aggregates. In this paper, I carefully account for these features in my quantitative work and go one step further by evaluating the optimal tax reforms.

Income Tax Credit (EITC) expansions between 1984 and 1996, on the one hand, reduced total family labor supply of couples mainly through lowering labor force participation of married women, and, on the other hand, increased participation of single women with children relative to single women without children. Borella et al. (2022) show that eliminating marriage-related taxes and old age Social Security benefits in the United States would significantly enhance married women's labor force participation over the life cycle. Kaygusuz (2010) claims that around a quarter of a 13-p.p. rise in labor force participation of married women in the United States between 1980 to 1990 can be attributed to the tax reforms of 1981 and 1986. Through the lens of a cross-country perspective, Bick and Fuchs-Schündeln (2017b) conclude that non-linear labor income taxation combined with the tax treatment of married couples accounts for a sizable share of variation in married women's hours of work across European countries.

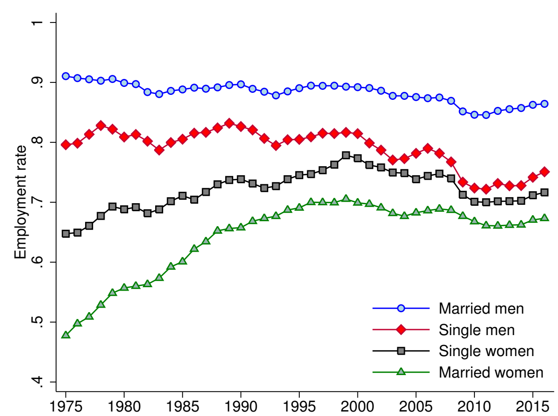
Female labor supply is often considered in the context of the so-called "added worker effect," i.e. a temporary increase in the labor supply of married women whose husbands have become unemployed (Lundberg, 1985). The evidence on this effect is mixed. On the one hand, using the PSID data, Blundell et al. (2016a) document that a sizable share of smoothing of men's and women's permanent shocks to wages operates through changes in spousal labor supply. Furthermore, Park and Shin (2020) also find the empirical support for the added worker effect by showing that wives significantly increase their labor supply—mainly through adjustments along the extensive margin—in response to an increase in the variance of permanent wage shocks of their husbands. On the other hand, Birinci (2019) and Busch et al. (2022) find that the magnitude of this effect is small.

Finally, human capital accumulation plays an important role in the model. Therefore, my work is also related to the literature that studies the interaction between human capital accumulation and income tax policy (Erosa and Koreshkova, 2007; Guvenen et al., 2014a; Stantcheva, 2017).

The rest of the paper is organized as follows. In Section 1.2, I document the empirical facts about labor supply and income taxation of single and married individuals in the United States. To build the intuition and explain the various channels through which tax progressivity affects singles and couples, in Section 1.3, I consider a simple static model.



(a) Average annual hours of work



(b) Employment rate

Figure 1.2: Labor Supply Trends by Gender and Marital Status in the United States

NOTES: I use the CPS data for individuals aged 25-65. Annual hours of work are constructed by multiplying the usual number of hours worked per week last year by the number of weeks worked last year. An individual is defined as employed if he/she worked a positive number of hours. I drop those who are employed but who report working less than 260 hours, those who report working more than 4160 hours, and those who earn less than half of the federal minimum wage.

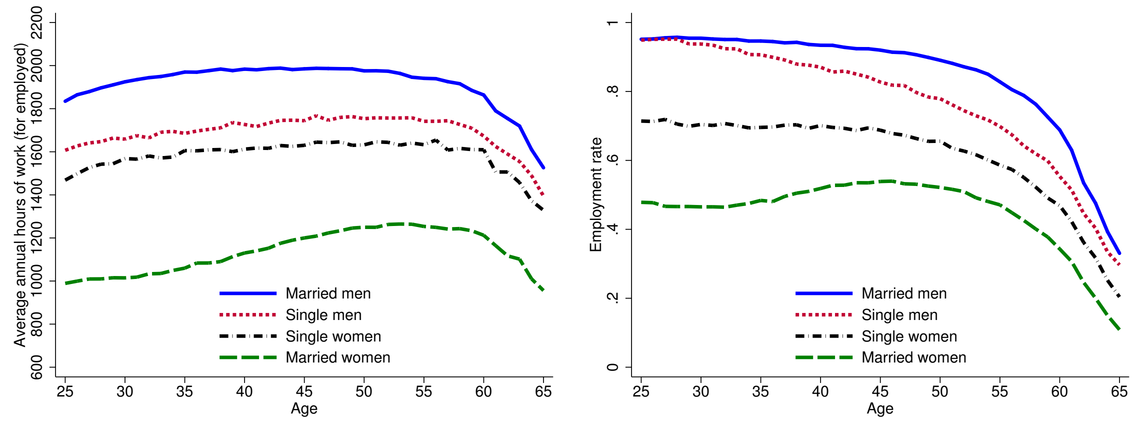
Section 1.4 lays out the full-fledged quantitative model. In Section 1.5, I discuss the parameterization and model fit. Section 1.6 describes the tax reforms and contains the quantitative results. In Section 1.7, I discuss the extensions of the baseline model and prospects for future research. Section 1.8 concludes.

1.2 Labor Supply and Income Taxation: Empirical Facts

In this section, I document the patterns of labor supply over time and over the life cycle for U.S. individuals that differ by gender and marital status. Next, I demonstrate that in the United States married secondary earners typically face higher participation tax rates relative to otherwise identical single individuals. In the subsequent sections, I will show that my quantitative model successfully matches the features described below.

I use the data from the CPS for the survey years 1976-2017.[4] The sample consists of single and married individuals aged 25-65. Annual hours of work are calculated by multiplying the usual number of hours worked per week last year (variable *uhrsworkly*) by the number of weeks worked last year (variable *wkswork1*). An individual is defined

[4] The data is extracted from IPUMS at https://cps.ipums.org/cps. See Flood et al. (2020).



(a) Average annual hours of work (for employed)

(b) Employment rate

Figure 1.3: Lifecycle Profiles of Labor Supply by Gender and Marital Status in the United States

NOTES: I use the CPS data for individuals aged 25-65. Annual hours of work are constructed by multiplying the usual number of hours worked per week last year by the number of weeks worked last year. An individual is defined as employed if he/she worked a positive number of hours. I drop those who are employed but who report working less than 260 hours, those who report working more than 4160 hours, and those who earn less than half of the federal minimum wage. The profiles are constructed by cleaning cohort effects following the usual procedure in the literature.

as employed if he/she worked a positive number of hours last year. I drop those who are employed but who report working less than 260 hours, those who earn less than half of the federal minimum wage, and those who report working more than 4160 hours, i.e. more than 80 hours per week for the entire year.[5] Finally, to ensure consistency, I drop individuals who report zero hours but positive earnings or zero earnings but positive hours.

1.2.1 Labor Supply over Time

I start my analysis by looking at the time series of labor supply between 1975 and 2016. In Figure 1.2, I report the average annual hours of work (left panel) and the employment rate (right panel) for single and married men and women. Consistent with the previous studies, the striking feature of the last several decades is the substantial increase in married women's labor supply (Knowles, 2013; Jones et al., 2015). Nowadays, their average hours

[5] In Figures A.2-A.3, I also report the time series and lifecycle profiles that are constructed using the information on the hours worked during the previous week (variable *ahrsworkt*). In this case, I drop those individuals who are employed and who report working less than 5 hours or more than 80 hours.

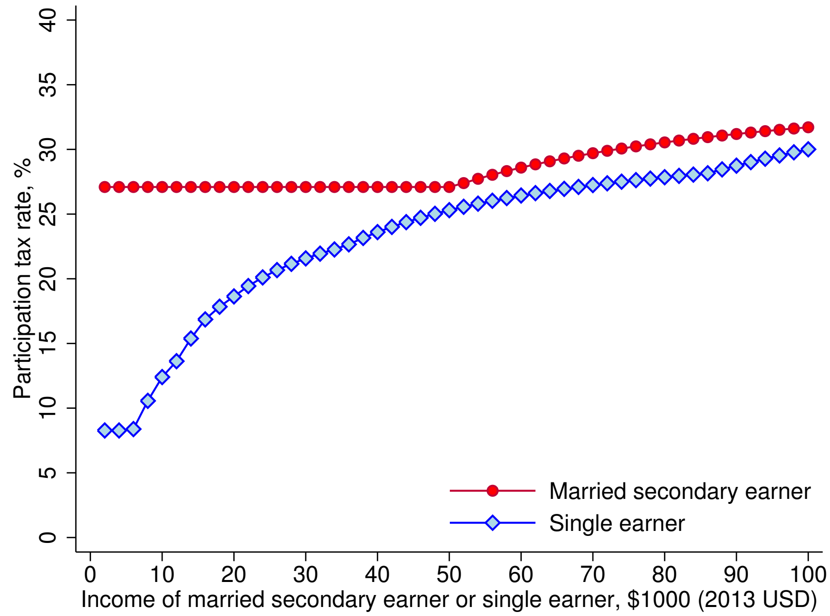


Figure 1.4: Participation Tax Rates of Single and Married Secondary Earners in the United States

NOTES: For the married secondary earner, the participation tax rate is defined as the additional tax burden that the couple faces if he/she goes from not working to working divided by his/her income. For the single earner, it is equal to the effective average tax rate. The tax rates are calculated using the NBER TAXSIM and include federal, state, and FICA tax rates. Both individuals aged 40, live in Michigan, and have two children under age 17. A secondary earner spouse's annual income is fixed at $35603 (2013 USD) which is the U.S. median level for 2013 (Song et al., 2019). Individuals do not have any non-labor income. Married couple is assumed to file jointly.

of work and employment rate are very close to those of single men and women. The other observation from Figure 1.2 is that single men's labor supply has not significantly changed over time while it has gone up for single women. As a result, the gap between them has narrowed down. Finally, the employment of married men has declined from 91.0% in 1975 to 86.4% in 2016. Motivated by the evidence from this section, in my model, I allow both men and women to make labor supply decisions at the intensive and extensive margins.

1.2.2 Labor Supply over the Life Cycle

Next, I look at the labor supply lifecycle profiles of men and women that differ by marital status. I follow the usual procedure in the literature, and construct them by cleaning cohort effects (Deaton and Paxson, 1994). The left panel of Figure 1.3 reports the average annual hours of work conditional on being employed. The right panel reports the employment rates. Consistent with the literature, employment and hours of employed men and women are hump-shaped, however, there is not much variation in hours over the life cycle (Attanasio et al., 2008; Erosa et al., 2016). Women have lower employment rates than men and work less hours conditional on being employed. Among four groups, married women has the lowest employment rate and hours of work.

1.2.3 Participation Tax Rates for Single and Married Secondary Earners

The fact that the combination of joint taxation of couples and tax progressivity creates substantial disincentive effects for married women's employment underscores the importance of accounting for the extensive margin of labor supply and human capital accumulation in my analysis (Bick and Fuchs-Schündeln, 2017a).[6] Under this policy, the marginal tax rate on the first dollar earned by the secondary (lower-income) earner is equal to the marginal tax rate on the last dollar earned by the primary (higher-income) earner. As a result, married secondary earners typically face higher tax rates than otherwise identical single earners. Figure 1.4 illustrates this point by showing the participation tax rates for single and married secondary earners in the United States. Intuitively, I calculate their average marginal tax rates if they go from not working to working. For the married secondary earner, I define his/her participation tax rate as the additional tax burden that the couple faces divided by his/her income:

$$\text{PTR} = \frac{\text{Taxes (dual-earner couple)} - \text{Taxes (single-earner couple)}}{\text{Secondary earner's income}}$$

For singles, it is simply equal to the effective average tax rate. Except for the marital status, two individuals in the figure are identical. I assume that the married person's spouse earns the median income. Furthermore, both households do not have any non-labor income. The key takeaway from this illustration is that the married secondary earner faces a significantly higher tax rate, when he/she starts working, than the single one.

[6] In the data, married women are more likely to be secondary earners.

1.3 Simple Example

To provide some intuition behind the different channels through which tax progressivity interacts with labor supply of singles and couples, I consider an analytically tractable static model. I demonstrate that the presence of private within-household insurance through spousal labor supply in couples reduces the desired degree of public insurance in the form of tax progressivity. Furthermore, I show that an increase in tax progressivity can lead to the opposite employment decisions of single individuals and secondary earners in couples. In Section 1.4, I enrich this environment by extending it to a general equilibrium setting and adding empirically relevant features (such as human capital accumulation and wage heterogeneity) that are necessary for a comprehensive quantitative analysis.

Consider two types of households—singles and married couples—making consumption and labor supply decisions. In particular, each individual decides whether to work or not and if work, then how much. If he/she works, then there is additional fixed time cost of work q. I interpret it as time spent on getting ready to work or the commuting costs. Modeling the participation margin with the fixed cost of work allows generating the distribution of hours that is consistent with the data (Cogan, 1981; French, 2005). Specifically, as Figure A.4 reports, the empirical distribution of weekly hours of work has a little mass at low positive numbers of hours. Instead, they are clustered around 0 and 40 hours. This is true for both men and women irrespective of their marital status. In the model, each person is endowed with one unit of time which is allocated between leisure, work, and fixed cost of work. Denote by w_m and w_f the labor market productivities (wage rates) of males and females, respectively. Households face the tax and transfer function that is given by

$$T(y) = y - \lambda y^{1-\tau} \tag{1.1}$$

where parameters λ and τ are allowed to vary by marital status. Parameter τ stands for the degree of tax progressivity. Given τ, parameter λ determines the average level of taxes in the economy. Single households pay taxes on their individual income, while married couples are taxed jointly, i.e. on the total income of spouses.[7] This functional form is

[7] While in the United States married couples can choose between separate and joint filing, most of them

widely used in the quantitative macroeconomics and public finance literature (Benabou, 2002; Heathcote et al., 2017). I discuss its properties in Appendix A.2.1.

First, consider the problem of a single individual with gender $i = m, f$:

$$\max_{c,n} \log(c) - \psi \frac{(n + q \cdot \mathbb{1}\{n > 0\})^{1+\eta}}{1+\eta} \tag{1.2}$$

$$\text{s.t.} \quad c = \lambda_s (w_i n)^{1-\tau_s} + \tilde{T}$$

where c denotes consumption, n denotes hours of work, $\mathbb{1}\{n > 0\}$ is an indicator for working positive number of hours (it equals to 1 if an individual works), and $\tilde{T}$ is a lump-sum government transfer. Parameters λ_s and τ_s characterize the tax schedule for single households.

Next, consider the problem of a married couple:

$$\max_{c,n_m,n_f} 2\log(c) - \psi \frac{(n_m + q \cdot \mathbb{1}\{n_m > 0\})^{1+\eta}}{1+\eta} - \psi \frac{(n_f + q \cdot \mathbb{1}\{n_f > 0\})^{1+\eta}}{1+\eta} \tag{1.3}$$

$$\text{s.t.} \quad c = \lambda_j (w_m n_m + w_f n_f)^{1-\tau_j} + 2\tilde{T}$$

where parameters λ_j and τ_j characterize the tax schedule for married couples.

First, consider the following comparative-static exercise. Suppose that an individual with gender i is hit by a productivity (wage) shock. In Proposition 1.1, I characterize the extent to which this shock translates into consumption movement.

choose the latter option. For example, in tax year 2018, 94.3% of married couples filed joint tax returns (see Table 1.6 "All Returns: Number of Returns, by Age, Marital Status, and Size of Adjusted Gross Income" in the Statistics of Income (SOI) data). Therefore, in the baseline version of my model, I assume that spouses are taxed on their joint income. In Section 1.7.3, I relax this assumption and allow married couples to choose between separate and joint filing.

Proposition 1.1 (Passthrough of Wage Shocks to Consumption). *Assume* $q = 0$ *and* $\tilde{T} = 0$*. For singles, the elasticity of consumption to wage shock is given by*

$$\frac{d\log(c)}{d\log\left(w_i\right)} = 1 - \tau_s \tag{1.4}$$

For couples, the elasticity of household consumption to wage shock of individual i *is given by*

$$\frac{d\log(c)}{d\log\left(w_i\right)} = \frac{w_i^{\frac{1+\eta}{\eta}}}{w_i^{\frac{1+\eta}{\eta}} + w_{-i}^{\frac{1+\eta}{\eta}}}\left(1 - \tau_j\right) \tag{1.5}$$

Proof. *See Appendix A.1.1.*

Proposition 1.1 shows how consumption of singles and couples responds to wage shocks, and how public insurance in the form of tax progressivity (τ_s and τ_j) affects these responses.[8] In particular, $(1 - \tau_s)\%$ of the shock passes through to single household consumption. For couples, the transmission coefficient is smaller than $(1 - \tau_j)$. It is mitigated because individual i's spouse adjusts his/her hours of work. Spousal labor supply serves as a private insurance against wage shocks, and it limits the role of tax progressivity as a social insurance device. Summing it up, Proposition 1.1 suggests that, ceteris paribus, this feature favors lower progressivity for couples. In Appendix A.1.1, I show that this result also holds in the environment where married couples are taxed separately rather than jointly.

I now discuss the effects of changes in tax progressivity on labor force participation of single individuals and married secondary earners in couples. The next two propositions show that an increase in tax progressivity can lead to the opposite results for these groups of people.

[8] Using the terminology from Blundell et al. (2008), I call the elasticities from Proposition 1.1 as transmission coefficients.

Proposition 1.2 (Tax Progressivity and Extensive Margin of Singles). *Define the threshold on fixed working cost $\bar{q}_s$ through the following equation:*

$$\underbrace{V_1^s\left(c_1^*, n^*; \bar{q}_s\right)}_{\text{work}} = \underbrace{V_0^s\left(c_0^*, 0\right)}_{\text{does not work}}$$

For singles whose income is below average, $w_i n_i < 1$, the fixed cost threshold is strictly increasing in progressivity, $\partial \bar{q}_s / \partial \tau_s > 0$, i.e. their labor force participation is increasing in progressivity.

Proof. *See Appendix A.1.2.*

Proposition 1.3 (Tax Progressivity and Extensive Margin of Married Secondary Earners). *Assume that the primary earners (males) do not face fixed working costs. Assume $\tilde{T} = 0$. Define the threshold on fixed working cost for married females $\bar{q}_c$ through the following equation:*

$$\underbrace{V_2^c\left(c_2^*, n_{m,2}^*, n_f^*; \bar{q}_c\right)}_{\text{dual-earner couple}} = \underbrace{V_1^c\left(c_1^*, n_{m,1}^*, 0\right)}_{\text{single-earner couple}}$$

Under joint taxation, if the primary earner's income is high enough, then the fixed cost threshold is strictly decreasing in progressivity, $\partial \bar{q}_c / \partial \tau_j < 0$, i.e. labor force participation of secondary earners is decreasing in progressivity.

Proof. *See Appendix A.1.3.*

I define a threshold value $\bar{q}_s$ for singles ($\bar{q}_c$ for secondary earners in couples) such that for singles with $q < \bar{q}_s$ (secondary earners with $q < \bar{q}_c$) it is optimal to work. In turn, with high enough values of q, singles and secondary earners choose not to work. Propositions 1.2 and 1.3 characterize the way these thresholds change with the degree of tax progressivity. On the one hand, higher tax progressivity encourages labor force participation of single individuals at the low end of the income distribution. Hence, a more progressive tax system creates a negative income effect on the labor supply of individuals whose income is below average. On the other hand, an increase in tax progressivity under joint taxation of spousal income discourages the labor force participation of the secondary earners. Joint taxation is often considered as one of the main factors that limits female labor force par-

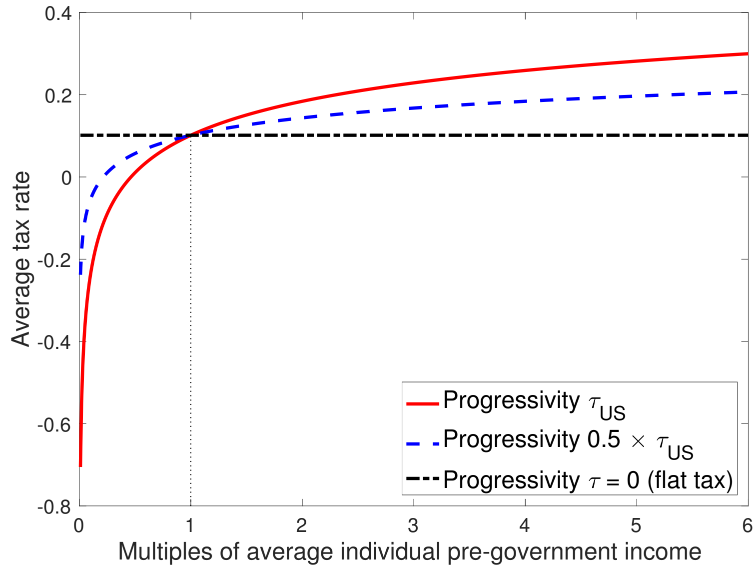


Figure 1.5: Average tax rate under different degrees of tax progressivity

NOTES: Parameters of the tax function for the United States are estimated using the data on single and married households from the Panel Study of Income Dynamics (PSID) for survey years 2013, 2015, and 2017, combined with the NBER TAXSIM (Feenberg and Coutts, 1993). See Appendix A.2.2 for the details.

ticipation in the United States and some European countries (Bick and Fuchs-Schündeln, 2017a). These disincentive effects can have long-run consequences because of human capital depreciation, a feature that I account for in my quantitative model.

To provide more intuition, in Figure 1.5, I plot the average tax rates against income relative to average income for different degrees of tax progressivity τ. The red solid line corresponds to the U.S. tax schedule.[9] Furthermore, the blue dashed line represents the less progressive tax schedule with the progressivity parameter that is equal to $0.5\tau_{US}$, and black dash-dotted line represents the flat tax system, i.e. $\tau = 0$. An increase in tax progressivity (e.g., moving from the blue dotted line to the red solid line) decreases the average tax rate for households whose income is below average and increases it for those whose income is above average.

Taking stock, the simple model studied here highlights the different implications of tax progressivity for singles and couples. The presence of private within-household insurance through responses of spousal labor supply in couples reduces the demand for public

[9] Note that I use Figure 1.5 for illustrative purposes only. In the quantitative part of this paper, I estimate the tax and transfer function separately for single and married households.

insurance in the form of tax progressivity. Furthermore, higher tax progressivity may result in the opposite effects for employment of single and married secondary earners.

1.4 Quantitative Model

In this section, I present an overlapping generations model that incorporates single and married households facing uninsurable idiosyncratic labor productivity shocks, intensive and extensive margins of labor supply, and human capital accumulation. It provides a natural framework to analyze the tax reforms. I focus on a balanced growth equilibrium where long-run growth is generated by exogenous technological progress and thus drop time subscripts.

Economic Environment. Consider a closed overlapping generations economy populated by a continuum of individuals that are either males (m) or females (f). I index gender by i, so that $i \in \{m, f\}$. Time is discrete. There are no aggregate shocks. The production side is described by a constant returns to scale technology. The government levies taxes, spends money, and runs a balanced-budget social security system.

Demographics. The economy is populated by A overlapping generations. Households are finitely lived, and their age is indexed by $a \in \{1, ..., A\}$. I assume that the population is constant. In each period, a unit measure of new agents is born. Each household is either a single (s) or a married couple (c). I index marital status by ι, so that $\iota \in \{s, c\}$. There are three types of households: single men, single women, and married couples. In the baseline model, I assume that agents are born as either single or married, and do not change the marital status over time. The life cycle of each individual is comprised of the working stage and retirement. During the working stage that runs from $a = 1$ to exogenous retirement age a_R, the agents have zero probability of dying. They choose how much to consume, work, and save. During the retirement stage, the agents do not work and face age-dependent survival probability ζ_a, and certainly die at age A, i.e. $\zeta_A = 0$. For tractability, I assume that spouses within each married couple have the same age and die at the same age.

Households. Household have preferences over consumption (c) and leisure (l). They discount the future at rate β. The momentary utility function for single household is given by

$$U^s(c,l) = \log(c) + \psi \frac{l^{1-\eta}}{1-\eta} \tag{1.6}$$

Married couples have joint utility function over (public) consumption and spousal leisure:

$$U^c\left(c, l^m, l^f\right) = \log\left(\frac{c}{\xi}\right) + \psi \frac{(l^m)^{1-\eta}}{1-\eta} + \psi \frac{\left(l^f\right)^{1-\eta}}{1-\eta} \tag{1.7}$$

where ξ denotes the consumption equivalence scale. Parameter ψ defines the utility weight attached to leisure and parameter η is the curvature of leisure that affects the Frisch elasticity of labor supply.

Each individual with gender i and marital status ι is endowed with $\bar{L}_\iota^i$ units of time that he/she splits between leisure and work. I interpret this time endowment to be net of home production, child care, and elderly care. Despite I do not explicitly model children, one can interpret lower $\bar{L}_\iota^i$ (and, therefore, less available time for leisure and work) as time costs associated with children. Furthermore, if an individual works, then he/she has to pay the fixed time cost of work. Therefore,

$$l_\iota^i = \bar{L}_\iota^i - n^i - q_\iota^i(a) \cdot \mathbb{1}\{n^i > 0\} \tag{1.8}$$

where n^i denotes hours of work, $\mathbb{1}\{n > 0\}$ is an indicator for working positive number of hours. The net time endowment is given by

$$\bar{L}_\iota^i = \frac{112}{1 + \exp\left(\varphi_\iota^i\right)} \tag{1.9}$$

where the gross time endowment is calculated as 168 hours (24×7 hours) minus 56 hours (8×7 hours) for sleep. I estimate φ_ι^i using the model.

I allow the fixed cost of work $q_\iota^i(a)$ to depend on gender, marital status, and age. Following Borella et al. (2022), I assume that it is described by a quadratic function of age[10]

$$q_\iota^i(a) = \frac{\exp\left(\alpha_0^{i,\iota} + \alpha_1^{i,\iota} a + \alpha_2^{i,\iota} a^2\right)}{1 + \exp\left(\alpha_0^{i,\iota} + \alpha_1^{i,\iota} a + \alpha_2^{i,\iota} a^2\right)} \tag{1.10}$$

and estimate parameters $\left(\alpha_0^{i,\iota}, \alpha_1^{i,\iota}, \alpha_2^{i,\iota}\right)$ using the model.

Human Capital. Women endogenously accumulate human capital through the labor market experience. In particular, following Attanasio et al. (2008), I assume that women's human capital evolves according to

$$h_{a+1} = h_a + (\varsigma_0 + \varsigma_1 a) \cdot \mathbb{1}\{n_a^f > 0\} - \delta_h \cdot \mathbb{1}\{n_a^f = 0\} \tag{1.11}$$

where ς_0 and ς_1 denote the returns to human capital, δ_h denotes human capital depreciation. Each period, if a woman works, her human capital increases by $\varsigma_0 + \varsigma_1$ units. I assume that the returns to human capital depend on age. Following Olivetti (2006) and Attanasio et al. (2008), if $\varsigma_1 < 0$, then I interpret it as the diminishing with age returns to human capital. In turn, if a woman does not work, it depreciates by δ_h units.[11]

Labor Productivity and Wages. During the working period, labor productivity of individuals depends on their human capital h (for women) or age a (for men), permanent ability υ, and persistent idiosyncratic shock u. I assume that retired individuals aged $a \geq a_R$ have zero labor productivity. Denote the experience efficiency profile for women by $g^f(h)$ and the age-efficiency profile for men by $g^m(a)$. Permanent ability $\upsilon^i \sim \mathcal{N}\left(0, \sigma_{\upsilon^i}^2\right)$ is drawn once at birth and accounts for differences in education and innate abilities. I allow the draws for spouses to be correlated (ρ_υ). This correlation measures the degree of assortative mating in the economy. Rich existing literature documents positive assortative mating by education in many countries, i.e. people with similar levels of education are more likely to marry each other (Pencavel, 1998; Greenwood et al., 2014; Eika et al., 2019).

[10] For example, this functional form allows to capture the role of child rearing for married women's labor force participation in a simple way.

[11] This formulation of human capital accumulation process is also close to the one described in Blundell et al. (2016b). They allow the returns to human capital to depend on whether a woman works full-time or part-time.

The idiosyncratic productivity shock u follows an AR(1) process:

$$u_a^i = \rho^i u_{a-1}^i + \varepsilon_a^i, \qquad \varepsilon_a^i \sim \mathcal{N}\left(0, \sigma_{\varepsilon^i}^2\right) \tag{1.12}$$

In each period, the log wage of a female characterized by age a, human capital h, permanent ability υ, and stochastic labor productivity u is given by

$$\log\left(\tilde{\omega}^f\left(a, h, \upsilon, u\right)\right) = \log\left(\tilde{w}\right) + \underbrace{\gamma_0^f + \gamma_1^f h + \gamma_2^f h^2 + \gamma_3^f h^3}_{\text{experience-efficiency profile, } g^f(h)} + \upsilon^f + u^f \tag{1.13}$$

where $\tilde{w}$ is the aggregate wage per efficiency unit of labor.[12] Thus, a female with $\left(a, h, \upsilon^f, u^f\right)$ has $\exp\left(g^f(h)\upsilon^f u^f\right)$ efficiency units of labor.

Similarly, the log wage of a male characterized by age a, permanent ability υ, and stochastic labor productivity u is given by

$$\log\left(\tilde{\omega}^m\left(a, \upsilon, u\right)\right) = \log\left(\tilde{w}\right) + \underbrace{\gamma_0^m + \gamma_1^m a + \gamma_2^m a^2 + \gamma_3^m a^3}_{\text{age-efficiency profile, } g^m(a)} + \upsilon^m + u^m \tag{1.14}$$

Thus, a male with (a, υ^m, u^m) has $\exp\left(g^m(a)\upsilon^m u^m\right)$ efficiency units of labor. I estimate the returns to age and experience using the PSID data.

Production. The production side of the economy is given by a representative firm that operates a constant returns to scale technology described by a Cobb-Douglas production function:

$$F_t\left(K_t, N_t\right) = K_t^\alpha \left(Z_t N_t\right)^{1-\alpha} \tag{1.15}$$

where K_t is capital input, N_t is labor input measured in efficiency units, and $Z_t = (1+\mu)^t Z_0$ is labor-augmenting technological progress. I normalize $Z_0 = 1$. Capital accumulation is standard and given by

$$K_{t+1} = \left(1-\delta\right) K_t + I_t \tag{1.16}$$

[12] As I explain later, I transform the growing economy into a stationary one, and therefore the wage per efficiency unit of labor $\tilde{w}$ is equal to the wage per efficiency unit of labor in a growing economy w_t divided by labor-augmenting technological progress Z_t.

where I_t is gross investment and δ is the capital depreciation rate.

The aggregate resource constraint is given by

$$C_t + K_{t+1} - (1-\delta)K_t + G_t \leq K_t^{\alpha}\left(Z_t N_t\right)^{1-\alpha} \tag{1.17}$$

In each period, the firm rents labor efficiency units at rate w and capital at rate r, and maximizes its profit

$$\pi_t = Y_t - \left(r_t + \delta\right)K_t - w_t N_t \tag{1.18}$$

Government. The government levies consumption and income taxes, spends collected revenues, and runs a balanced-budget pay-as-you-go Social Security system. Retired individuals receive Social Security benefits ss that are independent of their earnings history. These benefits are financed by proportional payroll taxes at exogenous rate τ_{ss}.[13] There are no annuity markets, and the assets of households that die are collected by the government and uniformly redistributed among households that are currently alive as accidental bequests ($\tilde{\Omega}$).

The government needs to finance an exogenously given level of government consumption G. It collects revenue from the following sources. First, there is a proportional consumption tax (t_c). Second, the government taxes household income of singles, $y^m = \tilde{\omega}^m\left(a, \upsilon, u\right)n^m$ and $y^f = \tilde{\omega}^f\left(h, \upsilon, u\right)n^f$, and couples $y^c = \tilde{\omega}^m\left(a, \upsilon, u\right)n^m + \tilde{\omega}^f\left(h, \upsilon, u\right)n^f$, where $\tilde{\omega}^f$ and $\tilde{\omega}^m$ are given in (1.13) and (1.14) correspondingly. I use the tax and transfer function of the form (1.1) and allow its parameters to vary by marital status of taxpayers. For singles, it is given by

$$T^s\left(y; \lambda_s, \tau_s\right) = y - \lambda_s y^{1-\tau_s} \tag{1.19}$$

Couples are taxed on the basis of joint spousal income,

$$T^j\left(y_m, y_f; \lambda_j, \tau_j\right) = y^m + y^f - \lambda_j\left(y^m + y^f\right)^{1-\tau_j} \tag{1.20}$$

[13] To reduce the computational burden, I assume that Social Security benefits do not depend on the earnings history, so that I do not need to keep track of Social Security contributions.

Market Structure. I assume that the asset market is incomplete, so that individuals cannot insure against idiosyncratic labor productivity risk by trading explicit insurance contracts. Furthermore, annuity markets are missing. Individuals can trade one-period risk-free bonds but cannot borrow.

1.4.1 Recursive Formulation

At any period of time, a single household is characterized by gender (i), asset holdings (b), human capital (h), permanent ability (υ^i), idiosyncratic labor productivity (u^i), and age (a).[14] Hence the individual state space for single males is $(m, b, \upsilon^m, u^m, a)$. The individual state space for single females is $\left(f, b, h, \upsilon^f, u^f, a\right)$. The individual state space for married couples is $(b, h, \boldsymbol{\upsilon}, \boldsymbol{u}, a)$, where $\boldsymbol{\upsilon} = \left(\upsilon^m, \upsilon^f\right)$ and $\boldsymbol{u} = \left(u^m, u^f\right)$. I transform the growing economy into a stationary one by deflating all appropriate variables by the growth factor Z_t.[15] I denote by $\tilde{x}$ the deflated variable x_t, i.e. x_t/Z_t. In what follows, I describe the problems of single and married households during the working and retirement stages of life.

Single Males (Working Stage). The recursive problem for a single male during the working stage is given by

$$V^m\left(\tilde{b}, \upsilon, u, a\right) = \max_{\tilde{c}, \tilde{b}', n} \left[U^m\left(\tilde{c}, l\right) + \beta \mathbb{E} V^m\left(\tilde{b}', u', \upsilon, a+1\right)\right] \tag{1.21}$$

subject to

$$(1+t_c)\,\tilde{c} + (1+\mu)\tilde{b}' = (1-\tau_{ss})\underbrace{\tilde{\omega}^m\left(a, \upsilon, u\right) n^m}_{\text{labor income}} + \underbrace{(1+r)\left(\tilde{b} + \tilde{\Omega}\right)}_{\text{savings + accidental bequests}} + \underbrace{\tilde{T}}_{\text{lump-sum transfers}} - T^s\underbrace{\left((1-0.5\tau_{ss})\,\tilde{\omega}^m\left(a, \upsilon, u\right) n^m + r\left(\tilde{b} + \tilde{\Omega}\right)\right)}_{\text{taxable income}} \tag{1.22}$$

$$l^m = \bar{L}_s^m - n^m - q_s^m(a) \cdot \mathbb{1}\{n^m > 0\} \tag{1.23}$$

$$\tilde{b}' \geq 0, \quad \tilde{c} > 0, \quad n^m \geq 0, \quad a < a_R \tag{1.24}$$

[14] Recall that human capital is a relevant state variable only for females.
[15] See King et al. (2002) for the discussion.

The expectation in (1.21) is taken over the next period's labor productivity shock.

Single Females (Working Stage). The recursive problem for a single female during the working stage is given by

$$V^f\left(\tilde{b}, h, \upsilon, u, a\right) = \max_{\tilde{c}, \tilde{b}', n}\left[U^f\left(\tilde{c}, l\right) + \beta \mathbb{E} V^f\left(\tilde{b}', h', u', \upsilon, a+1\right)\right] \tag{1.25}$$

subject to

$$\begin{aligned}(1+t_c)\,\tilde{c} + (1+\mu)\tilde{b}' = (1-\tau_{ss})\,\tilde{\omega}^f\left(h, \upsilon, u\right) n^f + (1+r)\left(\tilde{b} + \tilde{\Omega}\right) + \tilde{T} - \\ T^s\left((1-0.5\tau_{ss})\,\tilde{\omega}^f\left(h, \upsilon, u\right) n^f + r\left(\tilde{b} + \tilde{\Omega}\right)\right)\end{aligned} \tag{1.26}$$

$$l^f = \bar{L}^f_s - n^f - q^f_s(a) \cdot \mathbb{1}\{n^f > 0\} \tag{1.27}$$

$$h' = h + (\varsigma_0 + \varsigma_1 a) \cdot \mathbb{1}\{n^f > 0\} - \delta_h \cdot \mathbb{1}\{n^f = 0\} \tag{1.28}$$

$$\tilde{b}' \geq 0, \quad \tilde{c} > 0, \quad n^f \geq 0, \quad a < a_R \tag{1.29}$$

The expectation in (1.25) is taken over the next period's labor productivity shock.

Married Couples (Working Stage). The recursive problem for a married couple during the working stage is given by

$$V^c\left(\tilde{b}, h, \boldsymbol{\upsilon}, \boldsymbol{u}, a\right) = \max_{\tilde{c}, \tilde{b}', n^m, n^f}\left[U^c\left(\tilde{c}, l^m, l^f\right) + \beta \mathbb{E} V^c\left(\tilde{b}', h', \boldsymbol{\upsilon}, \boldsymbol{u}', a+1\right)\right] \tag{1.30}$$

subject to

$$\begin{aligned}(1+t_c)\,\tilde{c} + (1+\mu)\tilde{b}' = (1-\tau_{ss})\left[\tilde{\omega}^m\left(a, \upsilon, u\right) n^m + \tilde{\omega}^f\left(h, \upsilon, u\right) n^f\right] + (1+r)\left(\tilde{b} + 2\tilde{\Omega}\right) + \\ 2\tilde{T} - T^c\left(\sum_{i=m,f}(1-0.5\tau_{ss})\,\tilde{\omega}^i\left(h, a, \upsilon, u\right) n^i + r\left(\tilde{b} + 2\tilde{\Omega}\right)\right)\end{aligned} \tag{1.31}$$

$$l^m = \bar{L}^m_c - n^m - q^m_c(a) \cdot \mathbb{1}\{n^m > 0\} \tag{1.32}$$

$$l^f = \bar{L}^f_c - n^f - q^f_c(a) \cdot \mathbb{1}\{n^f > 0\} \tag{1.33}$$

$$h' = h + (\varsigma_0 + \varsigma_1 a) \cdot \mathbb{1}\{n^f > 0\} - \delta_h \cdot \mathbb{1}\{n^f = 0\} \tag{1.34}$$

$$\tilde{b}' \geq 0, \quad \tilde{c} > 0, \quad , n^m \geq 0, \quad n^f \geq 0, \quad a < a_R \tag{1.35}$$

The expectation in (1.30) is taken over the next period's labor productivity shocks for each of the spouses.[16]

Single Households (Retirement Stage). The recursive problem for a single individual with gender $i \in \{m, f\}$ during the retirement stage is given by

$$V^i\left(\tilde{b}, a, \upsilon\right) = \max_{\tilde{c}, \tilde{b}'} \left[U^i\left(\tilde{c}, \bar{L}_s^i\right) + \zeta_a \beta V^i\left(\tilde{b}', a+1, \upsilon\right)\right] \tag{1.36}$$

subject to

$$(1 + t_c)\,\tilde{c} + (1+\mu)\tilde{b}' = \underbrace{ss}_{\text{retirement benefits}} + (1+r)\left(\tilde{b} + \tilde{\Omega}\right) - T^s\left(ss + r\left(\tilde{b} + \tilde{\Omega}\right)\right) \tag{1.37}$$

$$\tilde{b}' \geq 0, \quad \tilde{c} > 0, \quad a \geq a_R \tag{1.38}$$

Married Couples (Retirement Stage). Finally, the recursive problem for a married couple during the retirement stage is given by

$$V^c\left(\tilde{b}, a, \upsilon\right) = \max_{\tilde{c}, \tilde{b}'} \left[U^c\left(\tilde{c}, \bar{L}_c^m, \bar{L}_c^f\right) + \zeta_a \beta V^c\left(\tilde{b}', a+1, \upsilon\right)\right] \tag{1.39}$$

subject to

$$(1 + t_c)\,\tilde{c} + (1+\mu)\tilde{b}' = 2ss + (1+r)\left(\tilde{b} + 2\tilde{\Omega}\right) - T^c\left(2ss + r\left(\tilde{b} + 2\tilde{\Omega}\right)\right) \tag{1.40}$$

$$\tilde{b}' \geq 0, \quad \tilde{c} > 0, \quad a \geq a_R \tag{1.41}$$

[16] In the baseline version of the model, they are assumed to be independent. I relax this assumption in Section 1.7.2.

1.4.2 Recursive Competitive Equilibrium

Let $\Pi^m\left(\tilde{b}, \upsilon, u, a\right)$ be the measure of single males, $\Pi^f\left(\tilde{b}, h, \upsilon, u, a\right)$ be the measure of single females, and $\Pi^c\left(\tilde{b}, h, \boldsymbol{\upsilon}, \boldsymbol{u}, a\right)$ be the measure of married couples. A stationary recursive competitive equilibrium is defined by

1. Given initial conditions, prices, transfers, and social security benefits, the value functions $V^m\left(\Pi^m\right)$, $V^f\left(\Pi^f\right)$, and $V^c\left(\Pi^c\right)$, and associated policy functions for consumption, hours, and savings, $\tilde{c}\left(\Pi^m\right)$, $n^m\left(\Pi^m\right)$, $\tilde{b}\left(\Pi^m\right)$, $\tilde{c}\left(\Pi^f\right)$, $n^f\left(\Pi^f\right)$, $\tilde{b}\left(\Pi^f\right)$, $\tilde{c}\left(\Pi^c\right)$, $n^m\left(\Pi^c\right)$, $n^f\left(\Pi^c\right)$, and $\tilde{b}\left(\Pi^c\right)$ solve the households' optimization problems.

2. Markets for labor, capital, and final output are clear:

$$\tilde{N} = \int \exp\left(g^m(a)\upsilon^m u^m\right) n^m d\Pi^m + \int \exp\left(g^f(h)\upsilon^f u^f\right) n^f d\Pi^f + \int \left(\exp\left(g^m(a)\upsilon^m u^m\right) n^m + \exp\left(g^f(h)\upsilon^f u^f\right) n^f\right) d\Pi^c \quad (1.42)$$

$$\tilde{K} = \int \tilde{b} d\Pi^m + \int \tilde{b} d\Pi^f + \int \tilde{b} d\Pi^c \quad (1.43)$$

$$\int \tilde{c} d\Pi^m + \int \tilde{c} d\Pi^f + \int \tilde{c} d\Pi^c + (\mu + \delta)\tilde{K} + \tilde{G} = \tilde{K}^\alpha \tilde{N}^{1-\alpha} \quad (1.44)$$

3. The factor prices satisfy:

$$\tilde{w} = (1-\alpha)\left(\frac{\tilde{K}}{\tilde{N}}\right)^\alpha \quad (1.45)$$

$$r = \alpha\left(\frac{\tilde{K}}{\tilde{N}}\right)^{\alpha-1} - \delta \quad (1.46)$$

4. The assets of dead households are uniformly redistributed among households that are currently alive:

$$\tilde{\Omega}\left(\int \zeta_a d\Pi^m + \int \zeta_a d\Pi^f + \int \zeta_a d\Pi^c\right) = \int (1-\zeta_a)\tilde{b} d\Pi^m + \int (1-\zeta_a)\tilde{b} d\Pi^f + \int (1-\zeta_a)\tilde{b} d\Pi^c \quad (1.47)$$

5. The social security system is budget balanced:

$$\tau_{ss}\tilde{w}\tilde{N} = ss\left(\int_{a\geq a_R} d\Pi^m + \int_{a\geq a_R} d\Pi^f + \int_{a\geq a_R} d\Pi^c\right) \tag{1.48}$$

6. The government budget is balanced:

$$\begin{aligned}\tilde{G} = t_c\left(\int \tilde{c}d\Pi^m + \int \tilde{c}d\Pi^f + \int \tilde{c}d\Pi^c\right) + \\ \int T^s\left((1-0.5\tau_{ss})\,\tilde{w}\exp\left(g^m(a)\upsilon^m u^m\right)n^m + r\left(\tilde{b}+\tilde{\Omega}\right)\right)d\Pi^m + \\ \int T^s\left((1-0.5\tau_{ss})\,\tilde{w}\exp\left(g^f(h)\upsilon^f u^f\right)n^f + r\left(\tilde{b}+\tilde{\Omega}\right)\right)d\Pi^f + \\ T^c\left((1-0.5\tau_{ss})\left(\tilde{w}\exp\left(g^m(a)\upsilon^m u^m\right)n^m + \tilde{w}\exp\left(g^f(h)\upsilon^f u^f\right)n^f\right) + r\left(\tilde{b}+2\tilde{\Omega}\right)\right)\end{aligned} \tag{1.49}$$

1.5 Parameterization

I now discuss the parameter choices for the model. I parameterize the model using a two-stage procedure (Gourinchas and Parker, 2002). In the first stage, I calibrate the parameters that can be set directly to their empirical counterparts without using the model. I take some parameter values from the literature, and estimate the remaining parameters directly from the data. In the second stage, I use the Method of Simulated Moments (MSM) (Pakes and Pollard, 1989; Duffie and Singleton, 1993). In Appendix A.3.2, I describe the estimation procedure in detail.

1.5.1 First-Stage Parameterization

Demographics. A model period is one year. The individuals enter the economy at age 25 (model age 1), retire at age 65 (model age 41) and live up to a maximum age of 100 (model age 76). I take the survival probabilities from “Life table for the total population: United States, 2014” provided by the National Center for Health Statistics. Table A.1 reports the survival probabilities for the ages 65-100. I take an adult equivalence scale from OECD, $\xi = 1.7$. Following Guner et al. (2012a), I set the share of married couples to be 77% of all

Table 1.1: Parameters Calibrated at the First Stage

Parameter	Description	Value	Source
a_R	Retirement age: 65 years	41	Standard
A	Maximum age: 100 years	76	Standard
ζ_a	Survival probability	Table A.1	NCHS
ξ	Adult equivalence scale	1.7	OECD
ϖ	Share of married couples	0.77	Guner et al. (2012a)
η	Leisure curvature	2	Erosa et al. (2016)
ς_0, ς_1	Returns to human capital	0.0266, -0.00038	Attanasio et al. (2008)
δ_h	Human capital depreciation	0.074	Attanasio et al. (2008)
γ_1^m, γ_2^m, γ_3^m	Age-efficiency profile, males	Text	PSID
γ_1^f, γ_2^f, γ_3^f	Experience-efficiency profile, females	Text	PSID
ρ^m, ρ^f	Productivity shock, persistence	0.937, 0.939	PSID
σ_{ε^m}, σ_{ε^f}	Productivity shock, st.dev.	0.187, 0.145	PSID
σ_{υ^m}, σ_{υ^f}	Permanent ability. st.dev.	0.332	PSID
α	Technology	0.36	Capital share
δ	Capital depreciation rate	0.0799	BEA, $I/K = 9.74\%$
μ	Growth rate	0.0175	U.S. data
τ_{ss}	Social security tax	0.106	Kitao (2010)
t_c	Consumption tax	0.052	Mendoza et al. (1994)
τ_s, τ_j	Tax progressivity	0.125, 0.147	PSID, NBER TAXSIM
G/Y	Government consumption	0.17	U.S. data

households.

Preferences. Following Erosa et al. (2016), I set parameter η that governs the Frisch elasticity of labor supply to 2. Discount factor β, the utility weight attached to leisure ψ, and parameters that govern net time endowment and fixed cost of work are estimated in the second stage.

Human Capital. Following Attanasio et al. (2008), I set $\varsigma_0 = 0.0266$ and $\varsigma_1 = -0.00038$. Negative ς_1 implies that the returns to human capital diminish with age. Furthermore, I set human capital depreciation rate to $\delta_h = 0.074$.

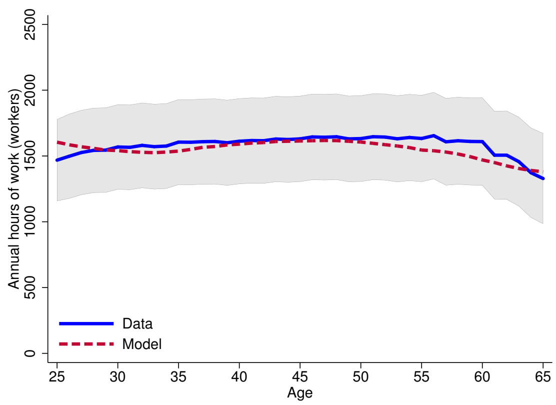
Labor Productivity. I estimate the age-efficiency profile for the wages of males (γ_1^m, γ_2^m, and γ_3^m) and experience-efficiency profile for the wages of females (γ_1^f, γ_2^f, and γ_3^f) using the PSID data. To control for selection into the labor market, I use a two-step Heckman approach. Having estimated the returns to age and experience, I use the residuals from regressions together with the panel structure of the PSID data to estimate the parameters of the productivity shock processes (ρ^m, $\sigma^2_{\varepsilon^m}$, ρ^f, and $\sigma^2_{\varepsilon^f}$) and the variance of permanent ability ($\sigma^2_{\upsilon^m}$ and $\sigma^2_{\upsilon^f}$), following the identification strategy by Storesletten et al. (2004). I normalize $\gamma^f_0 = 1$ and estimate γ^m_0 in the second stage.[17]

Production. I set $\alpha = 0.36$ to match the capital share. Furthermore, I set the capital depreciation rate $\delta = 0.0799$ to match the average U.S. investment-capital ratio of 9.74% reported by the U.S. Bureau of Economic Analysis (BEA) for 2012-2016. To match the long-run growth rate of the U.S. GDP per capita, I set $\mu = 0.0175$ (Conesa and Krueger, 2006).

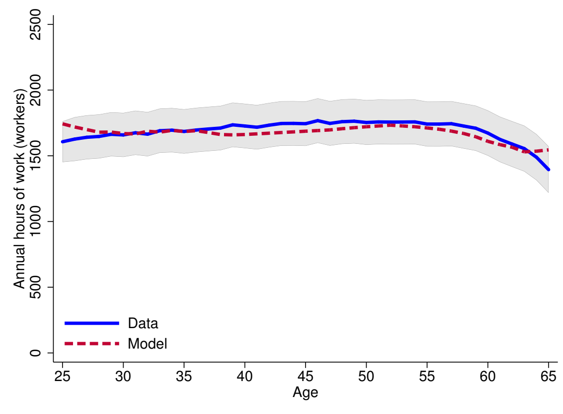
Government. Following Kitao (2010), I set the payroll tax rate to $\tau_{ss} = 10.6\%$. The retirement benefit ss is determined endogenously from the Social Security system budget constraint (1.48), and the resulting replacement rate is about 45%. Next, using the estimate from Mendoza et al. (1994), I set consumption tax rate to $t_c = 5.2\%$. Finally, I estimate the parameters of the tax and transfer functions (1.19) and (1.20) using the PSID data for waves 2013, 2015, and 2017 combined with the NBER TAXSIM (Feenberg and Coutts, 1993). The resulting values for the degree of tax progressivity are $\tau_s = 0.125$ and $\tau_j = 0.147$. My estimates are close to ones from Heathcote et al. (2017), who estimate $\tau = 0.181$ using the PSID and survey years 2000-2006, and Holter et al. (2019), who estimate $\tau_s = 0.111$ and $\tau_j = 0.158$ using the OECD tax and benefit calculator for years 2000-2007. They are higher than ones reported by Guner et al. (2014), who use the data from the Internal Revenue Service (IRS) 2000 Public Use Tax File, and hence do not account for transfers. Appendix A.2.2 discusses the estimation in detail. I choose the level of government consumption G so that in a balanced growth path its share in GDP is equal to 17%.

Table 1.1 summarizes the parameter values selected in the first stage.

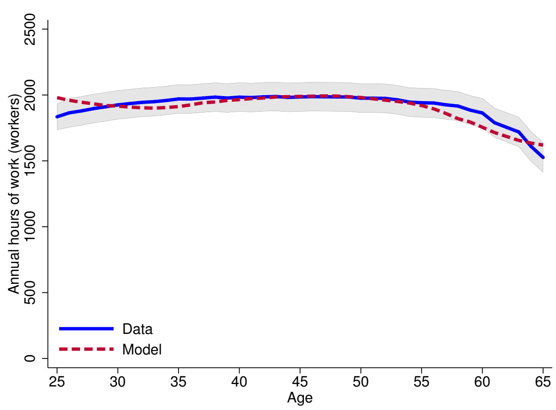
[17] Note that γ^m_0 should not be interpreted as the gender wage gap between 25-year-old males and females. This is due to the fact that the age-efficiency profile for men starts at 25 years, while the experience-efficiency profile for women starts at 0 years.



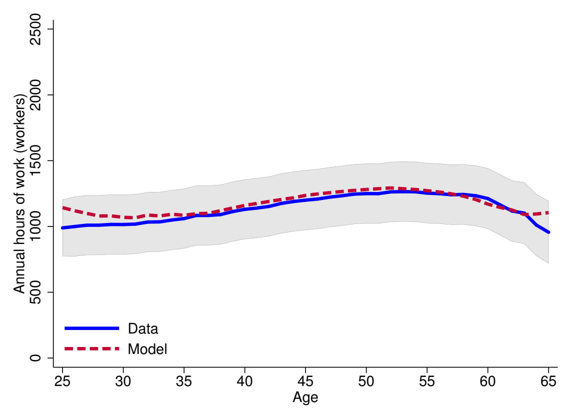
(a) Single men



(b) Single women



(c) Married men



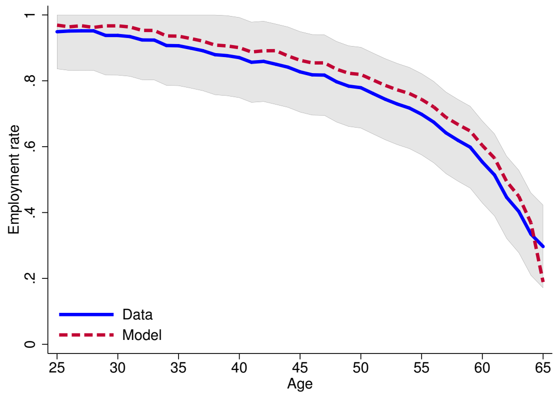
(d) Married women

Figure 1.6: Hours of Work over the Life Cycle, Model and Data

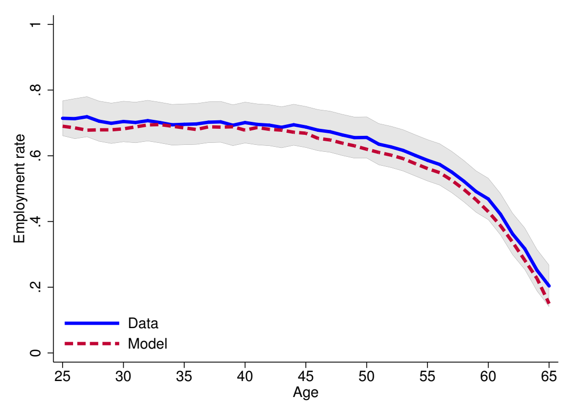
NOTES: The shaded area represents the 95% confidence interval.

Table 1.2: Parameters Estimated by the Method of Simulated Moments

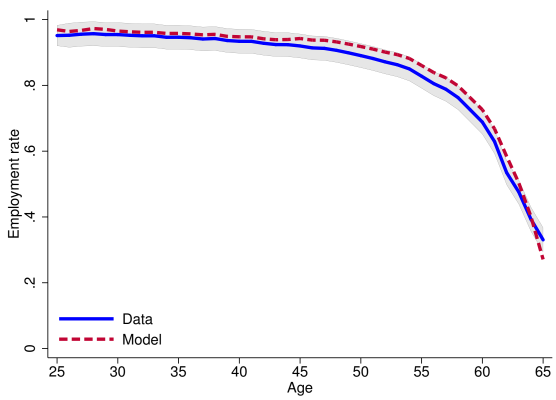
	Description	Value	Moment
β	Discount factor	0.996	Capital-output ratio
ψ	Taste for leisure	7.31	Working hours
γ_0^m	Male wage parameter	-1.092	Average gender wage gap
$\bar{L}_c^m$	Time endowment, married men	0.91	Working hours, married men
$\bar{L}_s^f$	Time endowment, single women	0.99	Working hours, single women
$\bar{L}_c^f$	Time endowment, married women	0.80	Working hours, married women
$\alpha_0^{i,\iota}, \alpha_1^{i,\iota}, \alpha_2^{i,\iota}$	Fixed costs of work	Text	Labor participation rates



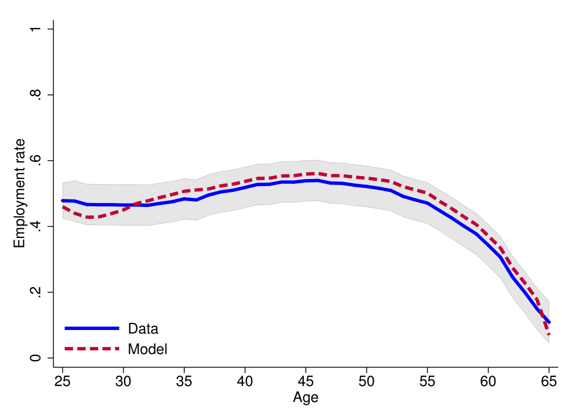
(a) Single men



(b) Single women



(c) Married men



(d) Married women

Figure 1.7: Participation over the Life Cycle, Model and Data

NOTES: The shaded area represents the 95% confidence interval.

1.5.2 Second-Stage Estimation

In the second stage, I estimate parameters $\left(\beta, \psi, \gamma_0^m, \left(\alpha_0^{i,\iota}, \alpha_1^{i,\iota}, \alpha_2^{i,\iota}\right), \bar{L}_\iota^i\right)$. I choose the following moments from the U.S. data to pin down these parameters: capital-output ratio, average female-to-male hourly wage ratio, labor market participation (employment) of single and married men and women between age 25 and age 65, and hours of work (conditional on working) of single and married men and women between age 25 and age 65. Table 1.2 summarizes the parameter values estimated in the second stage.[18]

[18] Net time endowments are expressed as fractions of the net time endowment for single males that I normalize to 112 hours.

1.5.3 Model Fit

In this section, I briefly discuss whether the model fits the data well. Figure 1.6 reports the lifecycle profile of hours of work (conditional on working) for single men and women and married men and women. As in the data, both male and female workers do not significantly vary the hours of work over the life cycle. Figure 1.7 reports the lifecycle profile of labor participation. As in the data, women (especially married) choose to enter the labor market relatively later than men. Overall, with relatively few parameters, the model can match well all the targeted moments.

Table 1.3: Model Fit

Moment	Data	Model
Capital-output ratio	3.2	3.17
Gender wage gap	0.72	0.729
Working hours	See Figure 1.6	See Figure 1.6
Labor participation rates	See Figure 1.7	See Figure 1.7

1.5.4 Model Performance

In this section, I verify how my model performs along the dimensions that are not targeted by calibration. In particular, given the crucial importance of labor supply elasticities in evaluating the effects of tax and transfer reforms, I report the model-implied compensated labor supply elasticities. To obtain them, I temporarily increase the wage for a particular gender-marital status-age group (e.g., single men aged 40) by 1%.

Table 1.4 reports the intensive margin labor supply elasticities for single men and women and married men and women by age groups. Table 1.5 reports the extensive margin labor supply elasticities for single men and women and married men and women by age groups. Remarkably, elasticities for men are lower than for women. Moreover, there is a substantial variation in extensive margin elasticities over the life cycle. Notably, participation elasticities are very high around the time of retirement. My estimates are consistent with the results from Attanasio et al. (2018).

Table 1.4: Model-Generated Intensive Margin Labor Supply Elasticities

Age	Single men	Single women	Married men	Married women
30	0.32	0.37	0.42	0.54
40	0.43	0.44	0.52	0.63
50	0.41	0.42	0.49	0.61
60	0.29	0.34	0.43	0.56

Table 1.5: Model-Generated Extensive Margin Labor Supply Elasticities

Age	Single men	Single women	Married men	Married women
30	0.16	0.57	0.02	0.96
40	0.21	0.42	0.11	0.73
50	0.47	0.45	0.19	0.64
60	1.24	1.92	0.71	1.13

1.6 Tax Reforms

In this section, I consider the main quantitative exercise. In particular, I take the Social Security system and consumption tax rate t_c as given and optimize the social welfare over income tax schedules that are allowed to be different for single and married households within a parametric class (1.1).

1.6.1 Optimal Policy

To rank tax functions, I use the social welfare function that is defined as the ex-ante steady state expected utility of newborn households. Formally, the problem of the utilitarian government is given by

$$SWF\left(\tau_s, \tau_j, \lambda_s, \lambda_j\right) = \int_{\left\{\left(\tilde{b}, h, \upsilon, \boldsymbol{u}, a\right): \tilde{b}=0, a=1\right\}} V^c\left(\tilde{b}, h, \upsilon, \boldsymbol{u}, a\right) d\Pi^c + \sum_{i=m,f} \int_{\left\{\left(\tilde{b}, h, \upsilon, u, a\right): \tilde{b}=0, a=1\right\}} V^i\left(\tilde{b}, h, \upsilon, u, a\right) d\Pi^i \quad (1.50)$$

Table 1.6: Aggregate Effects of Tax Reforms

Parameter/Variable	Benchmark	Optimal	Proportional	Fixed (w, r)
Progressivity τ_s	0.125	0.151	0	0.153
Progressivity τ_j	0.147	0.108	0	0.109
Interest rate	2.77%	2.41%	2.12%	2.77%
Wage rate	—	1.72%	2.68%	—
Aggregate hours	—	2.71%	3.72%	2.66%
Married women employment, %	0.692	0.718	0.731	0.717
Aggregate output	—	0.76%	2.04%	0.67%
Aggregate consumption	—	0.91%	1.77%	0.90%
Gini (consumption)	0.314	0.325	0.354	0.325
Welfare gain	—	1.31%	0.51%	1.27%

NOTES: In this table, I report the percentage change in macroeconomic variables for each tax reform. Column "Benchmark" corresponds to the status-quo economy.

In my revenue-neutral policy experiments, parameter λ_s endogenously adjusts to keep the government budget constraint balanced. By having one budget constraint, I allow for cross-redistribution between singles and couples.[19] The government chooses $(\tau_s, \tau_j, \lambda_j)$ so that[20]

$$\left(\tau_s^*, \tau_j^*, \lambda_j^*\right) = \underset{\tau_s, \tau_j, \lambda_j}{\operatorname{argmax}} \, SWF\left(\tau_s, \tau_j, \lambda_j; \lambda_s\right) \tag{1.51}$$

Table 1.6 reports the results. The first finding is that singles ($\tau_s^* = 0.151$) should be taxed more progressively than couples ($\tau_j^* = 0.108$). Second, I find that the optimal tax schedule has a higher degree of progressivity for singles and lower progressivity for couples relative to the actual income tax policy ($\tau_s = 0.125$ and $\tau_j = 0.147$). The optimal tax reform increases the couples' average elasticity of post-tax/transfer income to pre-tax/transfer income from 0.853 (under actual U.S. tax system) to 0.892 (under optimal tax system). This gives rise to an increase in married women participation by 2.6 p.p. (from 69.2% to 71.8%). Furthermore, replacing the U.S. tax and transfer system with the optimal schedule is associated with sizable welfare gain of 1.31% in consumption-equivalent terms.

[19] Another alternative is to have two separate government budget constraints, one for singles and one for couples. In this case, redistribution occurs within groups but not between them.

[20] Several papers challenge the assumption about utilitarian taste for redistribution (Moser and Olea de Souza e Silva, 2019; Heathcote and Tsujiyama, 2021; Wu, 2021). For example, Heathcote and Tsujiyama (2021), using the inverse-optimum approach, conclude that the current U.S. tax and transfer system is characterized by a weaker than utilitarian taste for redistribution.

In addition, I also consider a reform that replaces the current U.S. tax schedule with a flat tax system. In this case, $\tau_s = \tau_j = 0$. The results are reported in column "Proportional" of Table 1.6. Despite the aggregate output and aggregate consumption are higher under this reform relative to the optimal reform, it creates smaller welfare gain (0.51%). This reflects that there is a strong social demand for redistribution and insurance that the flat tax system cannot provide.

Finally, to evaluate the potential size of the bias that arises because I do not account for the transition to the optimal steady state, I compute the new steady state under optimal τ_s^* and τ_j^* but fixing the wage rate and interest rate at their benchmark levels. The last column of Table 1.6 shows that abstracting from changes in the capital stock between two steady states is not associated with significantly different welfare gain.

1.6.2 Distribution of Welfare Gains

In this section, I provide the decomposition of welfare gains from the optimal reform by permanent ability groups. I divide the population of men and women into four groups corresponding to the quartiles of the permanent ability distribution. Tables 1.7 and 1.8 report the results for singles and married couples correspondingly.

Table 1.7: Distribution of Welfare Gains for Singles

	Q1	Q2	Q3	Q4
Males	1.6%	0.8%	0.2%	-0.4%
Females	1.8%	0.8%	0.2%	-0.4%

NOTES: In this table, I report the distribution of welfare gains by permanent ability groups υ. The groups are defined as the quartiles of permanent ability distribution.

Table 1.8: Distribution of Welfare Gains for Married Couples

	Q1, females	Q2, females	Q3, females	Q4, females
Q1, males	0.4%	0.4%	0.6%	0.9%
Q2, males	0.4%	0.6%	0.8%	1.0%
Q3, males	0.5%	0.7%	1.1%	1.5%
Q4, males	0.9%	1.1%	1.6%	2.1%

NOTES: In this table, I report the distribution of welfare gains by permanent ability groups υ. The groups are defined as the quartiles of permanent ability distribution. "Q1" denotes the bottom 25% of permanent ability distribution. "Q4" denotes the top 25% of permanent ability distribution.

First, the welfare gains are positive for all groups except for the subgroup of singles in the top quartile (Q4) of the permanent ability distribution. Second, the welfare gains are not uniformly distributed. For singles, the gains decrease along the permanent ability distribution, ranging from 1.6-1.8% for the bottom quartile (Q1) to -0.4% for the top quartile. Couples where both spouses belong to the bottom quartile of the permanent ability distribution, gain around 0.4% in consumption-equivalent terms. In turn, couples where both spouses belong to the top quartile of the permanent ability distribution, gain around 2.1% in consumption-equivalent terms.

1.6.3 Partial Reforms

In the previous section, I consider the reforms that change the tax and transfer schedules for both singles and couples. Now I ask the following question. Is there a welfare-improving reform that replaces the actual U.S. income tax code with a revenue-neutral income tax system so that the schedule for one group (e.g., singles) remains at the benchmark level while the schedule for the other group (e.g., couples) is changed. Table 1.9 reports the results.

I find that these "partial" reforms deliver aggregate welfare gains. Reforming tax schedule for singles, while keeping the tax schedule for couples fixed, delivers the welfare of 0.71%. On the other hand, reforming the tax schedule only for couples is associated with the welfare gain of 0.52%.

Table 1.9: Aggregate Effects of Partial Tax Reforms

Parameter/Variable	Benchmark	Optimal	Optimal τ_s	Optimal τ_j
Progressivity τ_s	0.125	0.151	0.178	0.125
Progressivity τ_j	0.147	0.108	0.147	0.091
Welfare gain	—	1.31%	0.71%	0.52%

NOTES: In this table, I report the value of the parameters of the tax and transfer functions (1.19) and (1.20) under different reforms. The last line reports the welfare gain in consumption-equivalent terms. Column "Benchmark" corresponds to the status-quo economy. Column "Optimal τ_s" corresponds to the policy experiment where I keep progressivity for couples τ_j at the benchmark level and optimize over progressivity parameter for singles τ_s. Column "Optimal τ_j" corresponds to the policy experiment where I keep progressivity for singles τ_s at the benchmark level and optimize over progressivity parameter for couples τ_j.

1.6.4 What if We Abstract from Couples?

In this section, I consider the following exercise. Suppose that the government treat all the households as single individuals, and therefore everyone faces the same tax and transfer schedule. Furthermore, assume that the extensive margin of labor supply is not operative, so that everyone chooses to work positive number of hours (therefore, I also abstract away from human capital accumulation). In this environment, couples are treated as richer singles. What is the optimal tax policy recipe in this environment? Table 1.10 reports the results.

Table 1.10: Optimal Tax Policy in "Singles Only" Environment

	Benchmark	Optimal	Benchmark (All Singles)	Optimal (All Singles)
Progressivity τ_s	0.125	0.151	—	—
Progressivity τ_j	0.147	0.108	—	—
Progressivity τ	—	—	0.139	0.186
Welfare gain	—	1.31%	—	1.12%

NOTES: In this table, I report the value of the parameters of the tax and transfer functions (1.19) and (1.20) under different reforms. The last line reports the welfare gain in consumption-equivalent terms. Column "Benchmark" corresponds to the status-quo economy. Column "Benchmark (All Singles)" corresponds to the environment where I assume that economy is populated only by singles. Column "Optimal (All Singles)" corresponds to the optimal policy associated with this environment.

In this case, the government finds it optimal to increase the tax progressivity from $\tau = 0.139$ to $\tau^* = 0.186$. This experiment illustrates that explicitly modeling couples and accounting for the extensive margin of labor supply combined with human capital accumulation is qualitatively as well as quantitatively important for the optimal tax policy design.

1.6.5 Isolating the Changes in Tax Progressivity

In this section, I go one step further and ask how does the optimal tax schedule look like when the government varies the degree of progressivity but keeps the average tax rates at the status-quo level. As I show in Appendix A.2.1, with tax and transfer function 1.1, both marginal and average tax rates depend on parameters τ and λ. In particular, $MTR = 1 - \lambda(1-\tau)y^{-\tau}$ and $ATR = 1 - \lambda y^{-\tau}$. By changing the degree of tax progressivity as measured by parameter τ, the government also changes the parameter λ to balance the government budget. As a result, a new tax system can feature both new progressivity and a new average tax rate.

I follow the idea from Guvenen et al. (2014a), and consider the following policy experiment. Suppose that the government chooses the degree of tax progressivity τ and adjust the parameter λ so that the new tax system has the same average tax rates for singles and couples as in the benchmark economy. To balance the government budget, I adjust the lump-sum transfers. Would the result that the couples should be taxed less progressively than singles still remain? Table 1.11 reports the results.

Table 1.11: Tax Reform with Fixed Average Tax Rate

	Benchmark	Optimal (Baseline)	Optimal (+ Fixed ATR)
Progressivity τ_s	0.125	0.151	0.144
Progressivity τ_j	0.147	0.108	0.117
Welfare gain	—	1.31%	1.16%

NOTES: In this table, I report the value of the parameters of the tax and transfer functions (1.19) and (1.20) under different reforms. The last line reports the welfare gain in consumption-equivalent terms. Column "Benchmark" corresponds to the status-quo economy.

If the government changes the progressivity of the tax schedule for singles and couples but keeps their average tax rates at the pre-reform levels, the resulting policy again implies that couples should be taxed less progressively than singles.

1.7 Extensions

I consider several extensions of the model from Section 1.4. The goal of this section is to explore whether and how the main results from Section 1.6.1 change in the alternative environments where I relax some assumptions of the baseline model. As before, the government chooses the revenue-neutral optimal tax and transfer schedule by maximizing over parameters of tax functions (1.19) and (1.20).

1.7.1 Marriage and Divorce

In the baseline model, I assume that individuals are born with predetermined marital status and do not change it over the life cycle. Since the labor supply decisions substantially vary by age and marital status, it is desirable to have a plausible distribution of household types by age. In this section, I relax the assumption about fixed marital status, and model marriage and divorce as exogenous shocks in the spirit of Cubeddu and Ríos-Rull (2003), Chakraborty et al. (2015), and Holter et al. (2019). While accounting for the endogenous response of marriage and divorce rates to changes in tax policy is potentially important, the empirical literature finds that in the United States the magnitude of this impact is quite small. In other words, most individuals do not respond to tax incentives in their decisions about marriage and divorce (Alm and Whittington, 1995; Whittington and Alm, 1997; Alm and Whittington, 1999).[21] I assume that married individuals face an age-dependent probability of divorce (d_a). In turn, single individuals face an age-dependent probability of getting married (ϑ_a).

I follow the modeling approach of Holter et al. (2019) and allow for assortative mating by permanent ability (education) in the marriage market. To calculate the age-dependent probabilities of marriage and divorce, I use data from the Annual Social and Economic Supplement (ASEC) of the CPS for years 2013-2017. I assume that these probabilities do not depend on the birth cohort. Denote by m_a and d_a the probability for a single to get married and the probability for a married couple to divorce at age a correspondingly. I compute these objects from the following identities

$$\underbrace{\bar{M}(a+1)}_{\text{married at age } a+1} = \underbrace{m_a\left(1-\bar{M}(a)\right)}_{\text{divorced} \to \text{married}} + \underbrace{(1-d_a)\,\bar{M}(a)}_{\text{married} \to \text{married}} \tag{1.52}$$

$$\underbrace{\bar{D}(a+1)}_{\text{divorced at age } a+1} = \underbrace{(1-m_a)\,\bar{D}(a)}_{\text{divorced} \to \text{divorced}} + \underbrace{d_a \bar{M}(a)}_{\text{married} \to \text{divorced}} \tag{1.53}$$

where $\bar{M}(a)$ and $\bar{D}(a)$ denote the shares of married and divorced individuals at age a.

Parameter ϱ affects the probability of matching and hence captures the degree of assortative mating. When I parameterize the model, I estimate it using the Method of Simulated Moments by matching the correlation of hourly wages for married couples calculated from

[21] Using the U.S. data, Fisher (2013) estimates that a $1000 change in the marriage bonus or penalty is associated with a 1.7 p.p. (or 1.9%) change in the probability of marriage. This effect is substantially higher than in the other papers. For comparison, Persson (2020) finds that elimination of survivors insurance in Sweden raised the divorce rate by 10%.

the CPS. Table 1.12 reports the results.

Table 1.12: Optimal Tax Policy in Environment with Marriage and Divorce

	Benchmark	Optimal (Baseline)	Optimal (+ Marriage & Divorce)
Progressivity τ_s	0.125	0.151	0.148
Progressivity τ_j	0.147	0.108	0.111
Welfare gain	—	1.31%	1.34%

NOTES: In this table, I report the value of the parameters of the tax and transfer functions (1.19) and (1.20) under different reforms. The last line reports the welfare gain in consumption-equivalent terms. Column "Benchmark" corresponds to the status-quo economy without marriage and divorce shocks.

In an environment with marriage and divorce, the results are very close to those from the baseline optimal reform. Intuitively, in an economy characterized by positive assortative mating, the government should increase the extent of public insurance against ex-post heterogeneity by taxing couples more progressively. However, since I already allow the spousal permanent abilities to be correlated, introduction of marriage and divorce shocks does not significantly change the distribution of households with different marital status by permanent ability. The resulting welfare gain is equal to 1.34% which is almost the same as under the baseline optimal policy. Overall, the conclusions from Section 1.6.1 continue to hold.

1.7.2 Correlated Productivity Shocks of Spouses

In the baseline version of the model, I assume that the draws of idiosyncratic productivity shocks are independent between spouses. In this section, I relax this assumption and allow them to be potentially correlated. In particular, $\left(u^m, u^f\right)$ follow

$$u_a^m = \rho^m u_{a-1}^m + \varepsilon_a^m$$

$$u_a^f = \rho^f u_{a-1}^f + \varepsilon_a^f$$

where $\left(\varepsilon^m, \varepsilon^f\right) \sim \mathcal{N}\left(\mathbf{0}, \boldsymbol{\Sigma}_{\boldsymbol{\varepsilon}}\right)$ and

$$\boldsymbol{\Sigma}_{\boldsymbol{\varepsilon}} = \begin{pmatrix} \sigma_{\varepsilon^m}^2 & \rho^\varepsilon \sigma_{\varepsilon^m} \sigma_{\varepsilon^f} \\ \rho^\varepsilon \sigma_{\varepsilon^m} \sigma_{\varepsilon^f} & \sigma_{\varepsilon^f}^2 \end{pmatrix}$$

Using the estimate from Hyslop (2001), I set the correlation between spousal shocks to be $\rho^{\varepsilon} = 0.25$. Table 1.13 reports the results.

Table 1.13: Optimal Tax Policy in Environment with Correlated Spousal Productivity Shocks

	Benchmark	Optimal (Baseline)	Optimal (+ Correlated Shocks)
Progressivity τ_s	0.125	0.151	0.149
Progressivity τ_j	0.147	0.108	0.115
Welfare gain	—	1.31%	1.43%

NOTES: In this table, I report the value of the parameters of the tax and transfer functions (1.19) and (1.20) under different reforms. The last line reports the welfare gain in consumption-equivalent terms. Column "Benchmark" corresponds to the status-quo economy with idiosyncratic productivity shocks that are independent between spouses.

In an environment with positively correlated spousal labor productivity shocks, couples are taxed more progressively relative to the baseline optimal policy. Intuitively, this correlation strengthens the redistribution motive in order to insure against ex-post heterogeneity. Furthermore, higher positive correlation between spousal wages limits the degree of within-family insurance that operates through the changes in labor supply. The resulting welfare gain is slightly higher than under the baseline optimal policy. Nevertheless, the conclusions from Section 1.6.1 continue to hold.

1.7.3 Joint and Separate Filing for Couples

Despite in reality U.S. married couples can choose between joint and separate filing, almost all choose the former option, and therefore in the baseline model I assume that they are taxed on the basis of combined spousal income.[22] In this section, I consider a version of the model where couples can choose between two options. In particular, the tax and transfer function is given

$$T^c\left(y^m, y^f\right) = \min\left\{y^m + y^f - \lambda_j\left(y^m + y^f\right)^{1-\tau_j}, y^m + y^f - \lambda_{sep}\left(y^m\right)^{1-\tau_{sep}} - \lambda_{sep}\left(y^f\right)^{1-\tau_{sep}}\right\} \tag{1.54}$$

[22] There are some situations when filing separately is preferable to joint filing. For example, some high-income couples where both spousal earnings are close to each other, may end up with lower tax liabilities under separate rather than joint filing.

To keep tractability, I make several assumptions. First, I assume that singles and couples filing separately face the same degree of tax progressivity, i.e. $\tau_s = \tau_{sep}$. Second, in my optimal policy exercise, I keep the ratio between scale parameters λ_{sep}/λ_s at the level corresponding to the benchmark economy. I calibrate parameter λ_{sep} to match the fraction of the U.S. married couple filing separately.[23] Table 1.14 reports the results.

Table 1.14: Optimal Tax Policy in Environment with Joint and Separate Filing for Couples

	Benchmark	Optimal (Baseline)	Optimal (+ Separate Filing)
Progressivity τ_s	0.125	0.151	0.147
Progressivity τ_j	0.147	0.108	0.105
Progressivity τ_{sep}	—	—	0.147
Welfare gain	—	1.31%	1.48%

NOTES: In this table, I report the value of the parameters of the tax and transfer functions (1.19) and (1.20) under different reforms. The last line reports the welfare gain in consumption-equivalent terms. Column "Benchmark" corresponds to the status-quo economy where couples are always taxed on their joint income.

In an environment where couples can choose between joint and separate filing, couples filing jointly are taxed less progressively than singles and couples filing separately. Moreover, about 74% of couples choose to file jointly at lower progressivity than to file separately but at higher progressivity. The aggregate welfare gain is 1.48% which is slightly higher than under the baseline optimal policy. An obvious shortcoming of this policy exercise is that I assume similar tax progressivity for singles and couples filing separately. Exploring how different are the results if this assumption is relaxed is an interesting avenue for future research.

1.7.4 Future Research

To keep the model tractable, I make some simplifying assumptions. First, I use ex-ante steady state expected utility of newborn households as a measure of social welfare. As Krueger and Ludwig (2016) show, a full characterization of the transition path is very important for policy evaluation. Other recent papers that evaluate welfare over the transition include Bakış et al. (2015), Boar and Midrigan (2021), and Dyrda and Pedroni (2022).

[23] Using the SOI data, I calculate that in 2012-2016 the average fraction of these couples was equal to 5.3%.

A natural next step of this paper is to extend the analysis and account for the transition path towards the optimal steady state.

Next, to model couples, I use the unitary model of the households. An important avenue for future research is to characterize the optimal tax and transfer schedule in an environment where couples are modeled using a collective approach (Chiappori, 1988).

In this paper, I follow a Ramsey-style taxation literature and quantify optimal reforms within a parametric class of tax functions. A more general non-parametric Mirrleesian approach will allow to characterize the entire shape of the optimal tax and transfer schedule. One of the challenges that arises when we study the optimal tax schedule under this approach is multidimensional screening (as long as the couple's private type is given by a two-dimensional vector). Recent example of papers that characterize the optimal tax schedule in this environment include Moser and Olea de Souza e Silva (2019) and Alves et al. (2021). On top of that, it is interesting to explore how far are the welfare gains delivered by best policy in the class described by (1.1) from maximum potential welfare gains (Heathcote and Tsujiyama, 2021).

Finally, in the model, I do not distinguish between cohabiting couples and singles. Empirical studies document strong rise in cohabitation in the United States over the last 50 years (Gemici and Laufer, 2011; Blasutto, 2020). Exploring the implications of this phenomenon for the optimal fiscal policy is another fruitful avenue for future research.

1.8 Conclusion

In this paper, I characterize the optimal degree of tax progressivity for single and married households. To do this, I build and parameterize a general equilibrium overlapping generations model that incorporates single and married households, intensive and extensive margins of labor supply, human capital accumulation, and uninsurable idiosyncratic labor productivity risk. I show that the model matches the patterns from the data remarkably well, and hence it can be used as a laboratory to quantify the tax reforms.

My first finding is that tax progressivity in the United States should be lower for married couples than for singles. Second, the optimal tax reform reduces progressivity for couples and increases it for singles relative to the actual U.S. tax system. Furthermore, it results in higher married women's employment and generates welfare gain of about 1.3% in consumption-equivalent terms. Finally, I show that my results carry over into the other environments. In particular, I extend my baseline model by separately adding marriage and divorce shocks, correlation between labor productivity shocks of spouses, and the choice between joint and separate filing for couples.

My paper contributes to the literature that emphasizes the importance of accounting for heterogeneity in gender and marital status in the quantitative macroeconomic models. My findings suggest that explicitly modeling couples and accounting for the extensive margin of labor supply and human capital accumulation is qualitatively as well as quantitatively important for the optimal tax policy design.

Chapter 2

Welfare Effects of Labor Income Tax Changes on Married Couples: A Sufficient Statistics Approach

2.1 Introduction

What are the welfare effects of tax reforms on married couples? How are the welfare gains and losses distributed among them? The answers to these questions are of crucial importance for both academic economists and policymakers for several reasons. First, the scope is significant. Married couples constitute a sizable share of the population (e.g., they account for almost a half of all the U.S. households in 2019) and taxpayers (e.g., the number of tax returns of married couples filing jointly constitutes more than a third of all tax returns in the United States). Second, positive assortative mating, when similarly educated individuals tend to marry each other, is considered as one of the driving forces of between-household inequality (Dupuy and Weber, 2021). Therefore, it is crucial to know who benefits and who loses from the redistributive policies such as income taxation. Finally, the tax and transfer systems that feature jointness, such as in Germany and the United States, create substantial disincentive effects for the married women's labor supply (Bick and Fuchs-Schündeln, 2017a; Holter et al., 2019). Under joint taxation of spousal incomes, the marginal tax rate on the first dollar earned by the secondary (lower income) earner is equal to the marginal tax rate on the last dollar earned by the primary (higher income) earner. Figure 2.1 illustrates the last point by showing the participation tax rates (change in household's tax liability divided by woman's earnings when she starts working) for married and single women in the United States. Except for the marital status, these two women are otherwise identical. Clearly, a married woman faces a significantly higher tax rate, when she starts working, than a single one. A tax reform that results in lower participation tax rates, as shown by the difference between dashed and solid lines, can enhance employment of the married women. Overall, studying the positive aspects of income taxation of couples is critically important because it is closely related to a vast array of topics including between- and within-household inequality, female labor supply, marriage decisions, and so on.

In this paper, I develop a framework for studying the welfare effects of income tax changes on married couples. First, I build a static model of couples' labor supply that features both intensive and extensive margins. Using this model, I derive a tractable expression for welfare gains, resulting from any arbitrary small tax policy reform, as a function of several sufficient statistics: labor supply elasticities (elasticities of hours, cross-elasticities of spousal hours, and participation elasticity), policy parameters (pre-reform marginal and participation tax rates and their reform-induced changes), and labor income shares. In a transparent way, it allows decomposing the changes in aggregate efficiency gains into the effects that operate through labor supply responses. I use this sufficient statistics formula to quantify the welfare effects of four tax reforms, implemented in the United States over the last four decades. The reforms include the Tax Reform Act of 1986 (TRA 1986), the Omnibus Budget Reconciliation Act of 1993 (OBRA 1993), the Economic Growth and Tax Relief Reconciliation Act of 2001 (EGTRRA 2001), and the Tax Cuts and Jobs Act of 2017 (TCJA 2017). To map my expression for welfare gains to the data, I use the Current Population Survey combined with the NBER TAXSIM calculator.

Under the baseline parameterization, I estimate the efficiency gains from four tax reforms to range from -0.16 (OBRA 1993) to 0.62 (TCJA 2017) percent of aggregate labor income. The welfare gains per dollar spent range from 0.63 USD (OBRA 1993) to 1.10 USD (TCJA 2017). Overall, three reforms, the TRA 1986, the EGTRRA 2001, and the TCJA 2017, created aggregate welfare gains for married couples. A substantial part of these gains comes from the labor force participation responses of women. Furthermore, I also emphasize that the spousal cross-effects of working hours (change in working hours of one spouse resulting from the change in the net-of-tax rate of the other spouse) are quantitatively important. Abstracting from them can lead to substantial overestimation of efficiency gains. For example, if I abstract from the cross-effects in the case of the TRA 1986 reform, I overestimate the welfare gains by 34.6%. The sensitivity analysis, where I

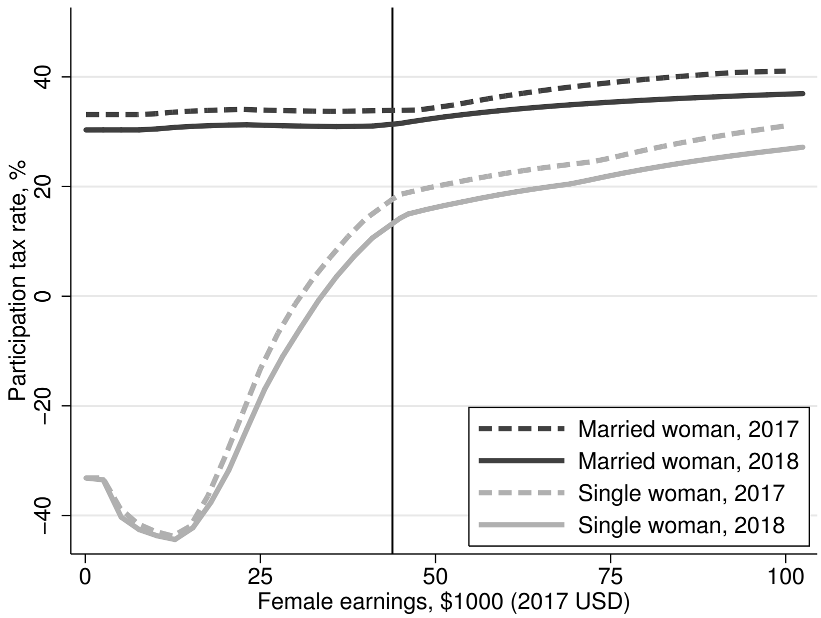


Figure 2.1: Participation Tax Rates of Married and Single Women in the United States

NOTES: Participation tax rate is defined as the change in household's tax liability divided by female earnings when she starts working. The tax rates are calculated using NBER TAXSIM and include federal, state, and FICA tax rates. Both women aged 40, live in Minnesota, and have two children under 19. A married woman husband's annual earnings are fixed at the median level in Minnesota. Individuals do not have any non-labor income. Married couple is assumed to file jointly. Vertical line corresponds to median annual female earnings in Minnesota (I multiply median weekly female earnings in Minnesota by median annual working hours of women in the United States divided by 40).

consider the range of reasonable values of elasticities, confirms this argument.

Next, despite three out of four considered reforms generate aggregate welfare gains, I find that each reform created winners and losers. For example, the TRA 1986 left 12.3 percent of couples with welfare losses. Furthermore, I study how the welfare gains vary by income and uncover two general patterns. First, the TRA1986, the OBRA 1993 (excluding the bottom 10 percent), and the TCJA 2017 reforms display a monotonically increasing relationship between welfare gains and income. In other words, richer taxpayers benefited more than poorer taxpayers. Second, the OBRA 1993 and the EGTRRA 2001 reforms demonstrate a U-shaped pattern in the welfare gains. In the case of these reforms, the main winners are located at the lower and upper ends of the income distribution. Overall, my general takeaway from this part of the analysis is that the aggregate welfare measures mask significant heterogeneity in welfare gains.

After that, I discuss the robustness of my findings. I start with considering alternative parameterizations of elasticities. Under the scenario that delivers an upper bound on the efficiency gains, I find that they range from -0.07 to 1.15 percent of aggregate labor income. Under the "lower bound" scenario, the range from -0.25 to 0.12 percent of the aggregate labor income. To address the concern that between the 1970s and 2000s there was a sizable reduction in own- and cross-elasticities of married women's labor supply (Blau and Kahn, 2007; Heim, 2007), I also consider the parameterization where all elasticities have reasonably high (and low) values. Next, to address the concerns about the role of the initial income distribution and pre-reform tax rates, I conduct two sets of counterfactual reforms. I begin with the exercises where I apply the actual tax reforms to the counterfactual income distributions. For example, I show that if the TRA 1986 reform were to be applied to the 2017 income distribution, aggregate welfare gains would be 1.32 percent of aggregate labor income, or 1.14 USD per dollar spent. This exceeds the actual welfare gains per dollar spent from the TCJA by 5.48%. Overall, I find that counterfactual welfare gains per dollar spent do not differ by more than 7.54% from the actual ones. In another set of exercises, I fix the income distribution and tax law in a given pre-reform year and calculate the welfare effects of moving to the other post-reform's tax law. For example, I show that moving from the pre-TRA 1986 economy to the post-EGTRRA 2001 and post-TCJA 2017 economies creates higher efficiency gains, 0.88 and 1.19 percent of aggregate labor income, than the actual TRA 1986 (0.55 percent). However, when I make the efficiency gains comparable, the actual TRA 1986 generates more welfare gain per dollar than these alternative counterfactual reforms.

Finally, I address the concern that the assumption about linearity of the tax function, commonly used in the sufficient statistics literature, may deliver biased estimates of efficiency gains, because real tax codes feature nonlinearities. To do so, I characterize the linearization bias, defined as the percentage difference between reform-induced efficiency loss under true and linearized tax and transfer functions. I assume quasilinear preferences and use the log-linear specification $T(y) = y - \lambda y^{1-\theta}$ that provides a good approximation of the actual tax and transfer system in the United States (Heathcote et al., 2017). More precisely, I consider joint, i.e. $T\left(y_m, y_f\right) = T\left(y_m + y_f\right)$, and separate, i.e.

$T(y_m, y_f) = T(y_m) + T(y_m)$, taxation of spouses. Assuming a small reform that changes progressivity of the tax system, $d\theta \approx 0$, I show that the linearization bias is given by the ratio between the tax progressivity parameter (tax function curvature) and the inverse elasticity of taxable income (utility curvature). Using the estimates of these objects from the literature, I conclude that linearization biases upward the welfare effects of the U.S. tax reforms in the range from 3.6% to 18.1%.

My paper is related to several strands of literature. First, I contribute to the literature studying the welfare effects of tax and transfer reforms initiated by the classic paper Harberger (1964), and further developed by Dahlby (1998), Feldstein (1999), Kleven and Kreiner (2006), and Blomquist and Simula (2019), among many others. On a related note, Finkelstein and Hendren (2020) and Hendren and Sprung-Keyser (2020) emphasize the attractiveness of the marginal value of public funds (MVPF) as a tool that allows comparing the effects of various policies on social welfare. The paper most closely related to mine is Eissa et al. (2008). They quantify the welfare effects of the U.S. tax reforms on single mothers. Importantly, the results for single individuals may be quite different from ones for married couples. First, the interactions between spouses, captured by the cross-elasticities of working hours, are naturally absent in a framework with singles. Second, single mothers more likely represent the lower part of the household income distribution than married couples, and any given tax reform may differently affect households that belong to different income groups. Another related work by Immervoll et al. (2009) studies the welfare effects of tax policy changes on married couples, but the authors consider hypothetical reforms. Instead, I evaluate the welfare gains of the actual U.S. tax reforms, including the most recent one, the Tax Cuts and Jobs Act of 2017. Furthermore, Bar and Leukhina (2009) investigate the impact of the U.S. tax reforms on married couples' participation but do not allow for the intensive margin of labor supply. Next, Hotchkiss et al. (2012) and Hotchkiss et al. (2021) evaluate the welfare effects of the U.S. tax reforms on households, but using a different approach than mine. Beyond that, two other related strands of literature study the macroeconomic effects of tax reforms (Barro and Redlick, 2011; Mertens and Ravn, 2012, 2013; Barro and Furman, 2018) and heterogeneity in the effects of economic policy (Domeij and Heathcote, 2004; Bitler et al., 2006; Zidar, 2019).

Next, my paper is related to the literature that studies the taxation of couples and its effects on the female labor supply. Eissa and Hoynes (2004) find that the Earned Income Tax Credit (EITC) expansions between 1984 and 1996 reduced the total family labor supply of couples mainly through lowering the labor force participation of married women. Next, Guner et al. (2012a), using a rich general equilibrium life-cycle model calibrated to the U.S. economy, show that the reform replacing joint taxation to separate taxation would substantially increase the labor supply of married women. Similarly, Bick and Fuchs-Schündeln (2017a) emphasize that joint taxation creates significant disincentive effects for the labor supply of married women in the United States and Europe. In the same vein, Borella et al. (2021) show that eliminating marriage-related taxes and old age Social Security benefits in the United States would significantly increase the participation of married women over their entire life cycle.

The rest of the paper is organized as follows. The model is presented in Section 2.2. The data and sample selection are discussed in Section 2.3. The U.S. tax reforms and construction of reform-induced tax changes using NBER TAXSIM are described in Section 2.4. The quantitative findings along with the sensitivity analysis, evidence on welfare gains distribution, and the results of the counterfactual reforms are reported in Section 2.5. The linearization bias is discussed in Section 2.6. Section 2.7 concludes.

2.2 Model

Economic Environment. To study the welfare effects of the changes in labor income taxes, I build a static model of married couples along the lines of Kaygusuz (2010) and Bick and Fuchs-Schündeln (2017b).[24] Consider an economy populated by N married couples. In each couple, spouses choose joint private consumption, c, males choose how much to work (intensive margin), h^m, and females choose whether to work (extensive margin) and, conditional on participation, how much to work (intensive margin), h^f. I abstract from modeling the extensive margin for males because in the data their participation rates are traditionally high and demonstrate little variation over time. Hence the households in the model are either single-earner or dual-earner couples. To model the extensive margin of

[24] Here and thereafter, I use “labor income taxes” and “taxes” interchangeably.

labor supply for women, I assume that each couple draw fixed utility cost of work q_i from a distribution $F_i(q_i)$. This cost is incurred when a wife enters the labor market. I interpret it as a utility loss that is related to inconvenience of scheduling joint work for both spouses or childcare responsibilities (Cho and Rogerson, 1988). Modeling the extensive margin with the fixed cost of work allows generating the distribution of hours that is consistent with the data. In particular, as Figure B.1 reports, the empirical distribution of married women's annual working hours has a little mass at low number of hours.

The wages of a male and a female in couple i are denoted by w_i^m and w_i^f correspondingly. The tax and transfer system is introduced by function $T\left(w_i^m h^m, w_i^f h^f, \theta\right)$. It embodies all labor income taxes and transfers and may feature non-separabilities between the arguments. I assume that $T(\cdot)$ is piecewise linear, so that the spouses face locally constant marginal tax rates. The policy reform is modeled in a flexible way by allowing $T(\cdot)$ to be a function of a treatment parameter θ. Changes in θ capture any arbitrary tax reform. In what follows, I focus on small reforms ($d\theta \approx 0$). Furthermore, I assume that there no other externalities than those operating through the government budget.

Household Optimization. The utility maximization problem of couple i is given by

$$\max_{c,h^m,h^f} U_i\left(c, h^m, h^f\right) = v_i\left(c, h^m, h^f\right) - q_i \cdot \mathbb{1}\{h^f > 0\} \tag{2.1}$$

$$\text{s.t.} \quad c = w_i^m h^m + w_i^f h^f - T\left(w_i^m h^m, w_i^f h^f, \theta\right) \tag{2.2}$$

where $v_i(\cdot)$ is a well-behaved utility function, and $\mathbb{1}\{h^f > 0\}$ takes the value one if the wife works and zero otherwise. Similarly to Eissa et al. (2008), my formulation accounts for the presence of income effects. This problem can be solved in two stages. First, conditional on wife's participation, the couple choose the hours of work. Second, the wife makes a participation decision at the optimal level of working hours. Consider these stages in turn.

First, given that both spouses work, $h^m > 0$ and $h^f > 0$, the optimal allocation for couple i is characterized by the following first-order conditions:

$$(1-\tau_i^j(\theta))w_i^j \frac{\partial v_i\left(c_i^2, h_i^{m,2}, h_i^f\right)}{\partial c} = -\frac{\partial v_i\left(c_i^2, h_i^{m,2}, h_i^f\right)}{\partial h^j}, \qquad j = m, f \tag{2.3}$$

where c_i^2 denotes the optimal consumption in a dual-earner couple, $h_i^{m,2}$ and h_i^f denote the optimal male's and female's hours of work in a dual-earner couple, and the effective marginal tax rates are denoted by $\tau_i^j(\theta) \equiv \partial T\left(w_i^m h_i^m, w_i^f h_i^f, \theta\right)/\partial\left(w_i^j h_i^j\right)$, with $j = m, f$. Note that these marginal tax rates include the marginal claw-back on special provisions of the tax code such as deductions or tax credits. To simplify notation, I omit explicit dependence of marginal tax rates on θ.

Next, at the second stage, the wife makes a decision whether to enter the labor market or not. There exists a threshold level of fixed cost of work, $\bar{q}_i$, such that the wife chooses to work if the utility of the dual-earner couple is greater than or equal to the utility of the single-earner couple. This threshold is given by

$$\bar{q}_i = v_i\left(c_i^2, h_i^{m,2}, h_i^f\right) - v_i\left(c_i^1, h_i^{m,1}, 0\right) \tag{2.4}$$

where $c_i^1 \equiv w_i^m h_i^{m,1} - T\left(w_i^m h_i^{m,1}, 0, \theta\right)$ denotes the optimal consumption of the single-earner couple. Consumption allocations of the dual-earner and single-earner couples are connected through the following equation:

$$c_i^2 = w_i^m h_i^{m,2} + w_i^f h_i^f - T\left(w_i^m h_i^{m,2}, w_i^f h_i^f, \theta\right) = c_i^1 + (1-a_i(\theta))\left[w_i^m\left(h_i^{m,2} - h_i^{m,1}\right) + w_i^f h_i^f\right] \tag{2.5}$$

where $a_i(\theta) \equiv \left[T\left(w_i^m h_i^{m,2}, w_i^f h_i^f, \theta\right) - T\left(w_i^m h_i^{m,1}, 0, \theta\right)\right] / \left(w_i^m\left(h_i^{m,2} - h_i^{m,1}\right) + w_i^f h_i^f\right)$ is a participation tax rate of the couple (Prescott, 2004). It captures the change in tax liability as a share of the change in earnings following the wife's decision to participate. In the quantitative part of this paper, I assume that the husband's earnings do not change if the wife enters the labor market, and hence a_i is effectively the women's participation tax rate. To simplify notation, I omit explicit dependence of participation tax rates on θ.

To evaluate the welfare effects of a tax policy reform, I obtain the compensated (Hicksian) consumption and labor supply by solving the expenditure minimization problem. This dual problem is given by

$$\min_{c,h^m,h^f} c - w_i^m h^m - w_i^f h^f + T\left(w_i^m h^m, w_i^f h^f, \theta\right) \tag{2.6}$$

$$\text{s.t.} \quad v_i\left(c, h^m, h^f\right) - q_i \cdot \mathbb{1}\{h^f > 0\} \geq \bar{U}_i \tag{2.7}$$

where $\bar{U}_i$ is some fixed level of utility.

Similarly to problem (2.1)-(2.2), I solve it in two stages. First, given that both spouses work, $h^m > 0$ and $h^f > 0$, the solution is characterized by the following first-order conditions:

$$(1-\tau_i^j)w_i^j \frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial c} = -\frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial h^j}, \qquad j = m, f \tag{2.8}$$

$$v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right) = \bar{U}_i + q_i \tag{2.9}$$

From (2.8)-(2.9), I get compensated consumption, $\tilde{c}_i^2 = \tilde{c}_i^2(\cdot)$, and labor supply, $\tilde{h}_i^{m,2} = \tilde{h}_i^{m,2}(\cdot)$ and $\tilde{h}_i^f = \tilde{h}_i^f(\cdot)$, for dual-earner couples. Using these compensated functions, I write down the expenditure function for a dual-earner couple:

$$E_i^2\left(\bar{U}_i + q_i, \theta\right) = \tilde{c}_i^2(\cdot) - w_i^m \tilde{h}_i^{m,2}(\cdot) - w_i^f \tilde{h}_i^f(\cdot) + T\left(w_i^m \tilde{h}_i^{m,2}(\cdot), w_i^f \tilde{h}_i^f(\cdot), \theta\right) \tag{2.10}$$

This expenditure function is evaluated at the current (pre-reform) tax and transfer system and depends on the treatment parameter θ both directly and through compensated consumption and labor supply.

For a single-earner couple, the solution to the dual problem is characterized by

$$(1-\tau_i^m)w_i^m \frac{\partial v_i\left(\tilde{c}_i^1, \tilde{h}_i^{m,1}, 0\right)}{\partial c} = -\frac{\partial v_i\left(\tilde{c}_i^1, \tilde{h}_i^{m,1}, 0\right)}{\partial h^m} \tag{2.11}$$

$$v_i\left(\tilde{c}_i^1, \tilde{h}_i^{m,1}, 0\right) = \bar{U}_i \tag{2.12}$$

and it delivers compensated consumption $\tilde{c}_i^1 = \tilde{c}_i^1(\cdot)$ and male's labor supply, $\tilde{h}_i^{m,1} = \tilde{h}_i^{m,1}(\cdot)$.

The expenditure function of a single-earner couple is given by

$$E_i^1\left(\bar{U}_i, \theta\right) = \tilde{c}_i^1(\cdot) - w_i^m \tilde{h}_i^{m,1}(\cdot) + T\left(w_i^m \tilde{h}_i^{m,1}(\cdot), 0, \theta\right) \tag{2.13}$$

Given utility $\bar{U}_i$, the wife chooses to enter the labor market if $E_i^2\left(\bar{U}_i + q_i, \theta\right) \leq E_i^1\left(\bar{U}_i, \theta\right)$, and not participate otherwise. Therefore, I write the expenditure function in the following way:

$$E_i\left(\bar{U}_i, q_i, \theta\right) = \min\left\{E_i^1\left(\bar{U}_i, \theta\right), E_i^2\left(\bar{U}_i + q_i, \theta\right)\right\} \tag{2.14}$$

Defining a compensated threshold of the fixed cost of work, $\tilde{q}_i$, such that $E_i^2\left(\bar{U}_i + \tilde{q}_i, \theta\right) = E_i^1\left(\bar{U}_i, \theta\right)$, and plugging (2.10) and (2.13) into this definition, I obtain the equation connecting compensated consumption in dual-earner and single-earner couples:

$$\tilde{c}_i^2 = \tilde{c}_i^1 + (1 - a_i)\left[w_i^m\left(\tilde{h}_i^{m,2} - \tilde{h}_i^{m,1}\right) + w_i^f \tilde{h}_i^f\right] \tag{2.15}$$

Furthermore, evaluating (2.9) and (2.12) at $\tilde{q}_i$, I get

$$\tilde{q}_i = v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right) - v_i\left(\tilde{c}_i^1, \tilde{h}_i^{m,1}, 0\right) \tag{2.16}$$

Setting $\bar{U}_i$ to be equal to the indirect utility obtained from problem (2.1)-(2.2), I guarantee that the solution to the expenditure minimization problem is consistent with the solution to the utility maximization problem.

Aggregate Labor Supply. Since the focus of the paper is in aggregate welfare effects of tax reforms, it is natural to ask how does a tax policy affect the aggregate labor supply of couples. Turning from individual optimization to the aggregates, I write down aggregate compensated labor supply:

$$\tilde{L}=\sum_{i=1}^{N}\Bigg[\underbrace{\int_{0}^{\tilde{q}_i}\tilde{h}_i^{m,2}\left((1-\tau_i^m)w_i^m,(1-\tau_i^f)w_i^f,\bar{U}_i+q_i\right)dF_i\left(q_i\right)}_{\text{compensated labor supply of males in dual-earner couples}}+$$
$$\underbrace{\int_{0}^{\tilde{q}_i}\tilde{h}_i^{f}\left((1-\tau_i^m)w_i^m,(1-\tau_i^f)w_i^f,\bar{U}_i+q_i\right)dF_i\left(q_i\right)}_{\text{compensated labor supply of females in dual-earner couples}}+$$
$$\underbrace{\int_{\tilde{q}_i}^{\infty}\tilde{h}_i^{m,1}\left((1-\tau_i^m)w_i^m,0,\bar{U}_i\right)dF_i\left(q_i\right)}_{\text{compensated labor supply of males in single-earner couples}}\Bigg] \quad (2.17)$$

The assumption about separability of q_i implies that the utility net of fixed cost of work, i.e. $v_i=\bar{U}_i+q_i$, is independent of the realization of q_i. Therefore, I rewrite (2.17) as

$$\tilde{L}=\sum_{i=1}^{N}\Bigg[\underbrace{F_i\left(\tilde{q}_i\right)}_{\text{affected by } a_i(\theta)}\underbrace{\left(\tilde{h}_i^{m,2}+\tilde{h}_i^{f}\right)}_{\text{affected by } \tau_i^m(\theta) \text{ and } \tau_i^f(\theta)}+\underbrace{\left(1-F_i\left(\tilde{q}_i\right)\right)}_{\text{affected by } a_i(\theta)}\underbrace{\tilde{h}_i^{m,1}}_{\text{affected by } \tau_i^m(\theta)}\Bigg] \quad (2.18)$$

where $F_i\left(\tilde{q}_i\right)$ denotes the probability of being a dual-earner couple or, alternatively, the individual probability of the woman's participation. This term can be also interpreted as the married women's participation rate. Aggregate compensated labor supply depends on extensive and intensive margins of spousal labor supply. The former affects $\tilde{L}$ through the woman's participation rate $F_i(\tilde{q}_i)$ that is driven by the participation tax rate a_i. The latter affects $\tilde{L}$ through the working hours that are driven by the marginal tax rates τ_i^m and τ_i^f. These labor supply behavioral responses are the key factors in assessing the efficiency gains of tax policy reforms.

Elasticities. To evaluate the welfare effects of a tax reform, I reformulate my results in terms of the compensated elasticities of labor supply. First, define the compensated participation elasticity as the percentage change in the woman's individual participation rate resulting from a one percentage change in the participation net-of-tax rate:

$$\eta_i \equiv \frac{\partial F_i\left(\tilde{q}_i\right)}{\partial\left(1-a_i\right)} \cdot \frac{1-a_i}{F_i\left(\tilde{q}_i\right)} \tag{2.19}$$

Next, define the compensated elasticity of working hours for males and females as the percentage change in working hours resulting from a one percentage change in the effective marginal net-of-tax rate:

$$\varepsilon_i^{m,\iota} \equiv \frac{\partial \tilde{h}_i^{m,\iota}}{\partial\left(1-\tau_i^m\right)} \cdot \frac{1-\tau_i^m}{\tilde{h}_i^{m,\iota}}, \qquad \iota=1,2 \tag{2.20}$$

$$\varepsilon_i^f \equiv \frac{\partial \tilde{h}_i^f}{\partial\left(1-\tau_i^f\right)} \cdot \frac{1-\tau_i^f}{\tilde{h}_i^f} \tag{2.21}$$

Finally, for dual-earner couples, define the cross-elasticities of working hours as the percentage change in individual's working hours resulting from a one percentage change in the effective marginal net-of-tax rate of his/her spouse. These elasticities are absent in the framework with singles.

$$\varepsilon_i^{mf} \equiv \frac{\partial \tilde{h}_i^{m,2}}{\partial\left(1-\tau_i^f\right)} \cdot \frac{1-\tau_i^f}{\tilde{h}_i^{m,2}} \tag{2.22}$$

$$\varepsilon_i^{fm} \equiv \frac{\partial \tilde{h}_i^f}{\partial\left(1-\tau_i^m\right)} \cdot \frac{1-\tau_i^m}{\tilde{h}_i^f} \tag{2.23}$$

Efficiency Loss. To study the effects of a tax reform on individual welfare, I define the measure of excess burden using the equivalent variation. Under this definition, the excess burden from the current tax and transfer system θ is the difference between the sum of money that the couple is willing to pay to move to the economy without distortionary taxes and transfers and collected tax revenue (Auerbach, 1985):

$$D_i\left(\bar{U}_i, q_i, \theta\right) = E_i\left(\bar{U}_i, q_i, \theta\right) - E_i\left(\bar{U}_i, q_i, 0\right) - R\left(\bar{U}_i, q_i, \theta\right) \tag{2.24}$$

where $R\left(\bar{U}_i, q_i, \theta\right)$ is given by

$$R\left(\bar{U}_i, q_i, \theta\right) = \begin{cases} T\left(w_i^m \tilde{h}_i^{m,2}(\cdot), w_i^f \tilde{h}_i^f(\cdot), \theta\right), & \text{if } q_i < \tilde{q}_i \\ T\left(w_i^m \tilde{h}_i^{m,1}(\cdot), 0, \theta\right), & \text{otherwise} \end{cases} \tag{2.25}$$

Aggregate excess burden under a tax and transfer system θ is defined as the sum of excess burdens over all couples:

$$D = \sum_{i=1}^{N} \int_0^{\infty} D_i\left(\bar{U}_i, q_i, \theta\right) dF_i\left(q_i\right) \tag{2.26}$$

Aggregate efficiency loss D measures additional revenue that can be collected, keeping couples at their initial utility levels $\bar{U}_i$, if the tax and transfer system θ were to be replaced by a lump-sum tax system. With heterogeneous agents, aggregate excess burden depends on the initial income distribution except under very strong conditions on preferences (Auerbach, 1985; Auerbach and Hines, 2002). In Section 2.5.4, I discuss the sensitivity of my results to alternative initial income distributions.

Plugging (2.14) and (2.25) into (2.24), I rewrite aggregate excess burden (2.26) as

$$D = \sum_{i=1}^{N} \left[\int_0^{\tilde{q}_i} \left(E_i^2\left(\bar{U}_i + q_i, \theta\right) - T\left(w_i^m \tilde{h}_i^{m,2}(\cdot), w_i^f \tilde{h}_i^f(\cdot), \theta\right)\right) dF_i\left(q_i\right) + \right.$$
$$\left. \int_{\tilde{q}_i}^{\infty} \left(E_i^1\left(\bar{U}_i, \theta\right) - T\left(w_i^m \tilde{h}_i^{m,1}(\cdot), 0, \theta\right)\right) dF_i\left(q_i\right) - \int_0^{\infty} E_i\left(\bar{U}_i, q_i, 0\right) dF_i\left(q_i\right) \right] \tag{2.27}$$

I focus on a small tax reform ($d\theta \approx 0$), and to capture its welfare effects, I study how aggregate efficiency loss D changes with θ. At this step, I refer to the envelope theorem and the assumption that there are no other externalities beyond those operating through the government budget, and show that any arbitrary small reform affects the expenditure function only through mechanical revenue effect, i.e. $dE_i^2\left(\bar{U}_i + q_i, \theta\right)/d\theta = \partial T\left(w_i^m \tilde{h}_i^{m,2}(\cdot), w_i^f \tilde{h}_i^f(\cdot), \theta\right)/\partial\theta$ for dual-earner couples and, similarly, $dE_i^1\left(\bar{U}_i, \theta\right)/d\theta = \partial T\left(w_i^m \tilde{h}_i^{m,1}(\cdot), 0, \theta\right)/\partial\theta$ for single-earner couples. Since the spouses optimize and there are no non-tax or non-transfer externalities, a small tax reform does not have the first-order effects on the expenditure functions and utility. In turn, the first-order effects come from externalities that operate through the government budget. In particular, when the spouses adjust their working hours or labor force participation, they create fiscal externality on all the other households. Having stated this, it follows from definition (2.24) that the effect of any arbitrary small tax reform on economic efficiency is captured by the behavioral revenue effect ("fiscal externality") or the difference between mechanical revenue effect, $\partial T_i/\partial\theta$, and total revenue effect, $dT_i/d\theta$.

Differentiating (2.27) and using the result from the previous paragraph, I obtain

$$\frac{dD}{d\theta} = -\sum_{i=1}^{N}\left[\tau_i^m w_i^m \frac{\partial \tilde{h}_i^{m,2}}{\partial\theta} F_i\left(\tilde{q}_i\right) + \tau_i^m w_i^m \frac{\partial \tilde{h}_i^{m,1}}{\partial\theta}\left(1 - F_i\left(\tilde{q}_i\right)\right) + \tau_i^f w_i^f \frac{\partial \tilde{h}_i^f}{\partial\theta} F_i\left(\tilde{q}_i\right) + a_i\left[w_i^m\left(\tilde{h}_i^{m,2} - \tilde{h}_i^{m,1}\right) + w_i^f \tilde{h}_i^f\right]\frac{\partial F_i\left(\tilde{q}_i\right)}{\partial\theta}\right] \quad (2.28)$$

The effect of a small tax reform on economic efficiency is driven by behavioral responses along intensive and extensive margins of labor supply. The first three terms in (2.28) stand for reform-induced changes in the working hours. The last term captures the effect of reform-induced changes in female labor force participation.

Denote aggregate labor income by

$$W \equiv \sum_{i=1}^{N}\left(w_i^m \tilde{h}_i^{m,2} + w_i^f \tilde{h}_i^f\right) F_i\left(\tilde{q}_i\right) + w_i^m \tilde{h}_i^{m,1}\left(1 - F_i\left(\tilde{q}_i\right)\right) \quad (2.29)$$

so that the expected labor income shares are given by $s_i^{m,2} \equiv w_i^m \tilde{h}_i^{m,2} F_i\left(\tilde{q}_i\right)/W$ for males in dual-earner couples, $s_i^{m,1} \equiv w_i^m \tilde{h}_i^{m,1}\left(1 - F_i\left(\tilde{q}_i\right)\right)/W$ for males in single-earner couples, and $s_i^f \equiv w_i^f \tilde{h}_i^f F_i\left(\tilde{q}_i\right)/W$ for females. Finally, in Proposition 2.1, I state the main formula that expresses the reform-induced change in economic efficiency in terms of the empirically estimable objects.

Proposition 2.1 (Reform-Induced Change in Economic Efficiency). *The effect of any arbitrary small tax reform $d\theta \approx 0$ on economic efficiency, captured by marginal excess* *burden as a fraction of aggregate labor income, is given by*

$$\frac{dD/d\theta}{W} = \sum_{i=1}^{N} \Bigg[\left(\frac{\tau_i^m}{1-\tau_i^m} \cdot \frac{d\tau_i^m}{d\theta} \varepsilon_i^{m,2} + \frac{\tau_i^m}{1-\tau_i^f} \cdot \frac{d\tau_i^f}{d\theta} \varepsilon_i^{mf} \right) s_i^{m,2} + \frac{\tau_i^m}{1-\tau_i^m} \cdot \frac{d\tau_i^m}{d\theta} \varepsilon_i^{m,1} s_i^{m,1} + \left(\frac{\tau_i^f}{1-\tau_i^f} \cdot \frac{d\tau_i^f}{d\theta} \varepsilon_i^{f} + \frac{\tau_i^f}{1-\tau_i^m} \cdot \frac{d\tau_i^m}{d\theta} \varepsilon_i^{fm} \right) s_i^{f} + \frac{a_i}{1-a_i} \cdot \frac{da_i}{d\theta} \eta_i \left(s_i^{m,2} + s_i^{f} - \frac{F_i\left(\tilde{q}_i\right)}{1-F_i\left(\tilde{q}_i\right)} s_i^{m,1} \right) \Bigg] \tag{2.30}$$

Proof. *See Appendix B.1.1.*

One of the advantages of using the sufficient statistics approach is the transparency of the results. In particular, using equation (2.30), I can decompose the aggregate effect of a tax reform into behavioral effects that operate through the men's working hours (the first and the third terms), the women's working hours (the fourth term), the spousal cross-effects of working hours (the second and the fifth terms), and, finally, the women's participation margin (the last term). It is useful to emphasize the difference between equation (2.30) and one that is obtained when households are modeled as single individuals. The first difference comes from the cross-elasticities, ε_i^{mf} and ε_i^{fm}, that capture the changes in individual's working hours induced by the changes in spousal net-of-tax rate. The existing estimates of these elasticities are different from zero (Blau and Kahn, 2007), even though the empirical evidence is quite limited. In Section 2.5, I show that these terms matter for the overall effect. Second, my framework also accounts for the changes in husband's working hours following the wife's decision to join the labor force. Neither of these terms are present in the setting without couples.

In what follows, I construct the effective marginal and participation tax rates, reform-induced changes in the effective tax rates, and the expected labor income shares using the Current Population Survey data and the Internet NBER TAXSIM tax calculator. Furthermore, I take the estimates of the elasticities from the literature and, to study the sensitivity of the results, consider different ranges of values. Next, using these empirical estimates in equation (2.30), I quantify the changes in economic efficiency caused by the tax reforms implemented in the United States over the last four decades.

2.3 Data

I use the data from the Annual Social and Economic Supplement (ASEC) of the Current Population Survey (CPS), or the "March CPS".[25] The March CPS contains data on annual earnings corresponding to the previous year. I define earnings as the sum of wage income and self-employment income. To be consistent with the model from Section 2.2, I focus on different-sex married couples with working husbands in which both a husband and a wife are aged 25-54. Since I do not model education or retirement decisions, I do not include younger or older individuals. Furthermore, I exclude the couples where husbands do not have a reasonably strong labor market attachment. In particular, I drop the households where a husband earns less than a time-varying minimum threshold defined as one-half of the federal minimum wage times 520 hours (13 weeks at 40 hours per week) which amounts to annual earnings of $1885 in 2012 USD (Guvenen et al., 2014b). Wives in my sample either work or not. To be consistent with the idea of reasonable labor market attachment of workers, I drop the couples where wives work but have annual earnings less than the time-varying minimum threshold described above. Using an alternative threshold of $100 in 2012 USD does not change the results.

It is well known that the household survey data is subject to several caveats. First, there are two types of non-response: non-interview and item non-response. In the March CPS, non-response is accounted for by imputing missing values. As pointed out by Meyer et al. (2015), the non-response rates in the major U.S. household surveys, including CPS, are growing over time. While imputation may cause serious problems for studying the trends over time, it works well if the object of interest is the cross-sectional distribution of individuals.[26] I consider each tax reform separately, and use the cross-sectional distribution of couples in each pre-reform year. By this reason, I do not exclude the observations with imputed values. Second, earnings in the survey data are subject to bottom- or top-coding. Until 1995, the CPS used the traditional top-coding when the respondents, who reported income over the maximum allowed value, were assigned this maximum

[25] The CPS data is extracted from IPUMS at https://cps.ipums.org/cps. See Flood et al. (2020).

[26] For this reason, it is quite common in the literature, studying the trends, to drop the observations with imputed data (Ziliak et al., 2011).

value. I drop all the top-coded and bottom-coded observations. In 1996-2010, the CPS used a replacement value system. The main difference with the traditional top-coding is that incomes above the maximum threshold are replaced by mean income of the other high-income individuals with similar demographic characteristics. Since 2011, the CPS has been using the rank proximity swapping procedure that preserves the distribution of values above the threshold. I do not drop the observations that are imputed using these procedures.

The summary statistics for the pre-reform years—1986, 1992, 2000, and 2017—is shown in Tables B.1 and B.2. Several things worth emphasizing. First, mean and median annual hours of males have barely changed since the 1980s. In turn, mean and median annual hours of females have significantly increased. For example, the median went from 1400 hours in 1986 to 1872 hours in 2017, a 34 percent increase. Second, the employment rates among married women do not display such a significant increase. This observation echoes the discussion about stagnating female labor force participation in the United States (Blau and Kahn, 2013). Third, in the 2010s the U.S. women are ahead of men in college education, even though in 1986 they were significantly behind (Goldin, 2014). Finally, although not reported, the share of families receiving welfare benefits, such as the Aid to Families with Dependent Children (AFDC) and Temporary Assistance for Needy Families (TANF) or the Supplemental Nutrition Assistance Program (SNAP), is small in my sample. Therefore, in the simulations, I do not account for welfare benefits that are lost when a wife enters the labor market.

2.4 The U.S. Tax Reforms

2.4.1 Background

My goal is to evaluate the welfare gains of the labor income tax changes on married couples induced by four reforms in the United States: the Tax Reform Act of 1986, the Omnibus Budget Reconciliation Act of 1993, the Economic Growth and Tax Relief Reconciliation Act of 2001, and the Tax Cuts and Jobs Act of 2017. While they affected various parts of the tax code, I focus exclusively on labor income taxes. In what follows, I describe the main reform-induced changes in the tax schedule for married couples filing jointly.

The top-left panel of Figure B.2 shows that the Tax Reform Act of 1986 significantly decreased the number of tax brackets. Despite the marginal tax rates were reduced for almost all the range of taxable income, they went up at the bottom of the income distribution and for the interval between $60000 and $69000 in 2012 USD. The top tax rate was decreased from 50 to 38.5 percent for tax year 1987, and then down to 28 percent in tax year 1988.[27] Next, as reported in Tables B.3 and B.4, there was an expansion in the EITC, standard deductions, and personal exemptions.

Next, the top-right panel of Figure B.2 reports that the Omnibus Budget Reconciliation Act of 1993 increased the top tax rate from 31 to 39.6 percent. Following the reform, the couples faced higher marginal tax rates for the taxable income above $222000 in 2012 USD. However, on the other hand, the OBRA 1993 significantly expanded the EITC, thus benefiting low-income households (Kleven, 2020). As a result, this reform could potentially have different effects on married women with working husbands than on the other groups sensitive to the changes in the tax and transfer system, such as single women (Eissa and Liebman, 1996; Eissa et al., 2008). The reason is that, in general, they belong to different parts of the income distribution, and the former are more likely affected by higher marginal tax rates rather than the EITC expansion.

The Economic Growth and Tax Relief Reconciliation Act of 2001 resulted into lower marginal tax rates for most tax brackets including the top income tax rate that went down from 39.6 to 35 percent. Moreover, the standard deduction for married couples filing jointly was increased relative to single filers. In particular, in 2000, the standard deduction for a married couple filing jointly was 67 percent higher than for a single filer, while in 2003 it became 100 percent higher.

Finally, the Tax Cuts and Jobs Act of 2017 featured changes in the federal income tax brackets and reduction in the marginal tax rates over almost the whole range of taxable income. The top income tax rate was decreased from 39.6 to 37 percent. Next, the standard deductions were increased, while personal exemptions were eliminated and itemized

[27] In 1988-1990, the marginal tax rate structure included a 5 percent surtax within some range of taxable income.

deductions were reduced. The individual income tax changes under the TCJA 2017 are effective for tax years 2018-2025. Moreover, there was a permanent shift from the Consumer Price Index (CPI) to the U.S. Chained Consumer Price Index (C-CPI-U) for indexing the tax brackets over time.

2.4.2 Reform-Induced Changes in Tax Rates

I calculate tax liabilities and reform-induced changes in tax rates for each couple in my sample using NBER TAXSIM calculator.[28] This software provides accurate representation of the U.S. tax code and allows capturing the heterogeneous effects of tax reforms on households. In related papers, Bick and Fuchs-Schündeln (2017b) and Bick et al. (2019) emphasize the importance of accounting for nonlinearities of the labor income tax code for studying the effects of tax and transfer system on labor supply of married couples.

For each spouse in my sample, TAXSIM returns the federal, state, and the Federal Income Contributions Act (FICA) tax liabilities as well as corresponding effective marginal tax rates. In Online Appendix, I provide the full list of input variables and describe how I fill each field. To be consistent with the model from Section 2.2, I abstract from all non-labor income. Next, because I do not explicitly model the children and childcare expenses, I set the number of children to two for each couple (this a median value for all the years in Tables B.1 and B.2). I also assume that all couples choose joint filing.[29] Finally, I assume that all the couples live in Michigan, a "typical area" in terms of state income taxation. Thus, heterogeneity in tax liabilities is solely driven by heterogeneity in couples' earnings. When I allow for variation in the factors that remain fixed in my analysis, the results do not significantly change.

To construct the participation and marginal tax rates, I need to know the potential earnings of all spouses, including non-working women. If a woman works, then I set her potential earnings to be equal to the actual earnings. If a woman does not work, her potential earnings are equal to her income in the case of entering the labor market. Since

[28] See Feenberg and Coutts (1993) for introduction to TAXSIM. Further details are available at https://www.nber.org/taxsim/.

[29] Married taxpayers in the United States pretty rarely file separate returns. According to IRS Income Statistics, in 2017 tax year about 95 percent of married couples filed jointly.

they are not observable, I apply a two-stage Heckman procedure to impute these earnings. I use the exclusion restrictions that the husband's earnings and the number of children under 6 do not directly influence the woman's earnings (Mulligan and Rubinstein, 2008; Bick and Fuchs-Schündeln, 2017b). Next, to obtain the expected labor income shares, I use the predicted probability of labor force participation as an empirical analogue of $F_i\left(\tilde{q}_i\right)$. Finally, I assume that workers bear the full incidence of employer payroll taxes. In this case, the proper measure of pre-tax labor income is equal to earnings plus the employer's share (50%) of the FICA tax. Hence, when I construct the tax rates, I divide all of them by the factor of $(1 + 0.5 \cdot \text{FICA})$.

For each woman in the sample, I construct an effective participation tax rate. In particular, for a woman in couple i it is given by

$$a_{it} = \frac{T_t\left(y_{it}^m, \hat{y}_{it}^f, Dem_{it}\right) - T_t\left(y_{it}^m, 0, Dem_{it}\right)}{\hat{y}_{it}^f} \tag{2.31}$$

where y_{it}^m denotes the husband's taxable income in year t, $\hat{y}_{it}^f$ denotes the wive's taxable income in year t, Dem_{it} denotes other TAXSIM inputs. I assume that the husband's earnings do not change when the wife enters the labor market.

The effective marginal tax rate in TAXSIM is calculated as the additional tax liabilities resulting from changing the taxable income by 10 cents. For example, for women it is given by

$$\tau_{it}^f = \frac{T_t\left(y_{it}^m, \hat{y}_{it}^f + \$0.1, Dem_{it}\right) - T_t\left(y_{it}^m, \hat{y}_{it}^f, Dem_{it}\right)}{\$0.1} \tag{2.32}$$

The left panel of Figure 2.2 reports the income-weighted mean effective marginal and participation tax rates for my sample. The tax rates include federal, state, and the FICA tax rates. Grey shaded areas represent the periods of reforms when the changes in taxes came into effect. On the one hand, the TRA 1986, the EGTRRA 2001, and the TCJA 2017 resulted in a decrease in the mean effective tax rates for the married couples. On the contrary, the OBRA 1993 led to an increase in the effective tax rates.[30] The drop in the tax

[30] This is different from its effect on single women. In particular, their effective marginal and participation tax rates dropped, mainly due to the EITC expansion (Eissa et al., 2008)

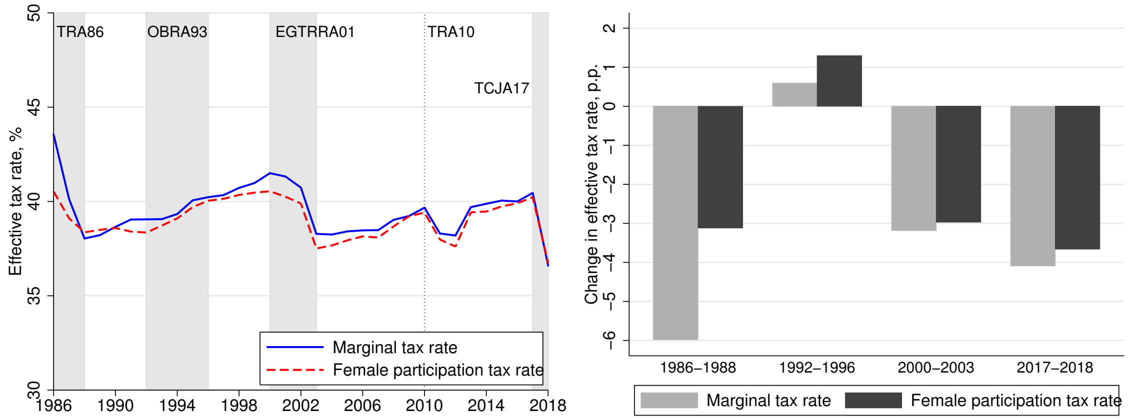


Figure 2.2: Mean Effective Marginal and Female Participation Tax Rates and Their Reform-Induced Changes

Notes: Left panel — Mean effective marginal and female participation tax rates. Right panel — Reform-induced changes in the mean effective marginal and female participation tax rates. Left Panel Notes: Marginal (solid blue) and participation (dashed red) tax rates include federal, state, and the FICA tax rates. Marginal tax rate series represents the mean marginal tax rate for males and females. Shaded areas indicate reform years. Right Panel Notes: To construct the changes, I apply the post-reform federal tax rules to the pre-reform taxable income and impute the post-reform federal income tax liabilities. The bars show the mean changes in the effective tax rates induced by the federal tax reforms. Changes in the marginal tax rates are calculated jointly for males and females.

rates resulting from the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010, that I do not analyze, was driven by a temporary reduction in the FICA tax.

The time series in the left panel of Figure 2.2 are driven by various factors, such as macroeconomic effects and behavioral responses. Furthermore, they capture the joint changes in the federal, state, and FICA tax rates. To isolate the changes in the effective tax rates separately induced by each federal tax reforms, I use the following procedure. For each spouse in pre-reform year t, I apply the federal tax rules of post-reform year $t + x$ to their year-t real taxable income, keeping the state and FICA tax rules at year-t level. Then I use the actual pre-reform and imputed post-reform federal tax liabilities to calculate the changes in the effective marginal and women's participation tax rates solely driven by the federal tax reforms. In this way, I find the empirical analogues of $d\tau_i^j/d\theta$ and $da_i/d\theta$. The mean changes in the tax rates are reported in the right panel of Figure 2.2.

2.5 Quantitative Results

2.5.1 Baseline Parameterization

To quantify the welfare effects of each tax reform separately, I take the pre-reform effective marginal and participation tax rates (2.31) and (2.32), the reform-induced changes in tax rates, the expected labor income shares, and the estimates of elasticities from the literature, and plug them into expression (2.30). Because I assume that husband's earnings do not change when his wife starts working, the last bracket in (2.30) simplifies to s_i^f. The welfare gains are defined as (2.30) taken with the negative sign.

The rich existing empirical evidence suggests that women respond more along the participation margin rather than working hours margin when face tax and transfer changes (Bargain et al., 2014). As for men's elasticities, many studies suggest that their elasticity of working hours is very low and can almost be ignored for welfare purposes (Meghir and Phillips, 2010). The evidence on the cross-wage labor supply effects, that is crucial for my framework, is quite limited. In a related work, Gayle and Shephard (2019), using the tax schedule corresponding to 2006, obtain the model-simulated working hours cross-elasticity is -0.08 for married men and -0.17 for married women. These numbers are, in general, consistent with existing empirical estimates (Blau and Kahn, 2007). Among other factors, the hours cross-elasticities may depend on the number of young children (Blundell et al., 2018). It is also worth noting that women's labor supply elasticities feature significant heterogeneity at the micro level, and any aggregate elasticity depends on the particular economic environment (Attanasio et al., 2018).

Under the baseline parameterization, I set the elasticity of male hours to 0.05, the elasticity of female hours to 0.1, women's participation elasticity to 0.6, the hours cross-elasticity of males to -0.05, and the hours cross-elasticity of females to -0.1. In Section 2.5.2, I conduct sensitivity analysis by varying the magnitudes of elasticities.

Beyond evaluating the actual welfare effects of tax reforms, it is also instructive to consider a benchmark case corresponding to a representative couple. This environment features no heterogeneity in income, tax rates, and tax rate changes. I assume $\tau^m = \tau^f$ because of tax system jointness. The pre-reform tax rates, τ and a, are given by the mean

Table 2.1: Welfare Effects of Labor Income Tax Changes on Married Couples with Working Husbands

Reform	Welfare gain, % of aggregate labor income							Tax Liab. Reduc., %	Δ Welfare/ $ Spent
	Intensive Males	Intensive Females	Extensive Females	Cross-Effects	Total w/o C.E.	Total	RC		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
TRA86	0.19	0.18	0.45	-0.27	0.82	0.55	0.44	7.20	1.08
OBRA93	-0.01	-0.02	-0.15	0.03	-0.18	-0.16	-0.16	0.27	0.63
EGTRRA01	0.09	0.12	0.40	-0.17	0.61	0.44	0.42	7.19	1.07
TCJA17	0.10	0.17	0.57	-0.22	0.84	0.62	0.58	6.58	1.10

Notes: Welfare gains are calculated using (2.30) taken with the negative sign. I set $\varepsilon^m = 0.05$, $\varepsilon^f = 0.15$, $\varepsilon^{mf} = -0.05$, $\varepsilon^{fm} = -0.1$, and $\eta = 0.6$. The pre-reform tax rates and reform-induces changes in tax rates are calculated using NBER TAXSIM applied to the ASEC CPS data. Column (5) shows total welfare gains when the cross-effects are ignored, and calculated as $(1) + (2) + (3)$. Column (6) shows total welfare gains, and calculated as $(4) + (5)$. Column (7) shows the welfare gains in a representative-couple economy. Column (9) is calculated as $(8)/[(8) - (6)]$, where (8) is the decrease in tax liabilities as a share of labor income before behavioral responses.

effective marginal and participation tax rates reported in the left panel of Figure 2.2. The reform-induced tax changes, $d\tau/d\theta$ and $da/d\theta$, are given by the mean changes in the tax rates reported in the right panel of Figure 2.2. Overall, the expression for the effect of a small tax reform on economic efficiency is simplified to

$$\frac{dD/d\theta}{W} = \frac{\tau}{1-\tau} \cdot \frac{d\tau}{d\theta} \left[\left(\varepsilon^m + \varepsilon^{mf} \right) s^m + \left(\varepsilon^f + \varepsilon^{fm} \right) s^f \right] + \frac{a}{1-a} \cdot \frac{da}{d\theta} \eta s^f \tag{2.33}$$

where $s^m = w^m h^m / W$ denotes the labor income share of men, and $s^f = w^f h^f F\left(\tilde{q}\right)/W$ denotes the labor income share of women.

Table 2.1 reports the welfare gains for married couples resulting from each of four considered U.S. tax reforms. Total welfare gains (column 6) are decomposed into four parts: behavioral effects created along the intensive margin of men's labor supply (column 1), the intensive margin of women's labor supply (column 2), the participation margin of women (column 3), and, finally, the spousal cross-effects of working hours (column 4). To emphasize the quantitative importance of cross-effects, in column (5), I show total welfare gains if we abstract from them. Effectively, column (5) is the sum of own effects given in columns (1), (2), and (3). Column (7) displays the welfare gains calculated in a representative-couple economy, according to (2.33). Furthermore, to facilitate comparison across the reforms, in column (9), I report the welfare gain per dollar spent.

First, Table 2.1 shows that reform-induced changes in federal income tax rates result in the welfare gains that range from -0.16 to 0.62 percent of aggregate labor income. These numbers reflect the welfare effects that are driven by the labor supply behavioral responses. Three reforms—the TRA 1986, the EGTRRA 2001, and the TCJA 2017—created aggregate welfare gains, while the OBRA 1993 created welfare loss. Second, it follows from comparing columns (5) and (6) that the spousal working hours cross-effects are quantitatively important and therefore should not be ignored in the welfare analysis of policies. Otherwise, it may lead to overestimation of the welfare effects. For example, if I abstract from the cross-effects, I overestimate the welfare gains from the TCJA 2017 by 34.6%. While this number seems to be high, the sensitivity analysis in Section 2.5.2 confirms the argument that the spousal cross-effects remain quantitatively important under any reasonable values of elasticities. The next conclusion from Table 2.1 is that the women's participation margin accounts for the bulk of total welfare gains. Again, ignoring this factor may lead to sizable bias in the estimates of policy welfare effects (Kleven and Kreiner, 2006; Eissa et al., 2008). Another lesson from Table 2.1 is that a representative couple model, that uses the income-weighted mean tax rates and mean changes in tax rates, deliver the results that are close to ones reported in column (6). Hence, if we are primarily interested in assessing *aggregate* welfare gains from tax reforms, a representative agent model may be a reasonable candidate device for this purpose. Finally, from the values in column (9), I conclude that the welfare gains vary between 0.63 and 1.10 USD per dollar spent.

The results reported in Table 2.1 provide a transparent decomposition of the aggregate welfare effects, thus highlighting one of the advantages of a sufficient statistics approach. Furthermore, when I construct the reform-induced changes in tax rates and then use them in formula (2.30), I focus solely on the tax-driven labor supply behavioral responses. My results are not affected by the other incentives created by the reforms. For example, the TRA 1986 reform led to a shift of income that was previously labeled as corporate income to personal income (Guvenen and Kaplan, 2017). Despite these clear advantages, I also discuss the potential caveats and the ways to address them. First, my framework assumes that the reforms are small, and the measured efficiency gains represent a first-order approximation of the true effects. I use the pre-reform tax rates in (2.30), however the reforms change the tax rates. The first-order approximation overstates the welfare gains of tax reductions and understates the welfare losses of tax increases (Kleven, 2021). The only case that can be considered as a large reform is the reduction in the top tax rate during the TRA 1986. However, when I use the trapezoid approximation to evaluate the effects of this reform, the results do not dramatically change. Furthermore, since I consider each reform separately, I take into account the second-order effects across the reforms. Second, the elasticities may move in response to the reforms as well. Blau and Kahn (2007) and Heim (2007) report that between the 1970s and 2000s there was a dramatic reduction in own- and cross-elasticities of married women's labor supply. To address this caveat, I conduct sensitivity analysis using different combinations of elasticities. For example, moving from the 1980s to the 2010s may be viewed as moving from the "high-elasticity" to the "low-elasticity" parameterization described in Section 2.5.2. Furthermore, there is substantial heterogeneity in labor supply elasticities, and the aggregate elasticities are not structural parameters (Attanasio et al., 2018). To address this concern, I conduct sensitivity analysis and construct the lower and upper bounds for the welfare effects using reasonable ranges of elasticities. Finally, I derive (2.30) under the assumption that the tax and transfer function is linear. In Section 2.6, I show that the linearity assumption leads to overestimation of the welfare gains and characterize this linearization bias.

2.5.2 Sensitivity Analysis

To explore the sensitivity of my results, I consider several alternative parameterizations of elasticities. The results are reported in Table 2.2. First, I begin with the "upper-bound" scenario. Under this parameterization, own elasticities have reasonably high values ($\varepsilon^m = 0.1$, $\varepsilon^f = 0.2$, and $\eta = 0.8$) and cross-elasticities have reasonably low values ($\varepsilon^{mf} = 0$ and $\varepsilon^{fm} = -0.05$) for the TRA 1986, the EGTRRA 2001, and TCJA 2017 reforms, i.e. the reforms that feature reductions in the mean effective tax rates. On the contrary, for the OBRA 1993, I assume low own elasticities ($\varepsilon^m = 0$, $\varepsilon^f = 0.1$, and $\eta = 0.4$) and high cross-elasticities ($\varepsilon^{mf} = -0.1$ and $\varepsilon^{fm} = -0.15$). Under the "upper-bound" parameterization,

Table 2.2: Welfare Effects of Labor Income Tax Changes on Married Couples, Sensitivity Analysis

Reform	Welfare gain, % of aggregate labor income							Tax Liab. Reduc., %	Δ Welfare/ $ Spent
	Intensive Males	Intensive Females	Extensive Females	Cross-Effects	Total w/o C.E.	Total	RC		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
“Upper-Bound” Parameterization: $\varepsilon^m = 0.1$, $\varepsilon^f = 0.2$, $\varepsilon^{mf} = 0$, $\varepsilon^{fm} = -0.05$, $\eta = 0.8$									
TRA86	0.39	0.24	0.60	-0.08	1.23	1.15	1.03	7.20	1.19
OBRA93*	0.00	-0.01	-0.10	0.04	-0.12	-0.07	-0.25	0.27	0.79
EGTRRA01	0.18	0.16	0.54	-0.04	0.88	0.84	0.77	7.19	1.13
TCJA17	0.19	0.23	0.76	-0.06	1.18	1.12	1.03	6.58	1.21
“Lower-Bound” Parameterization: $\varepsilon^m = 0$, $\varepsilon^f = 0.1$, $\varepsilon^{mf} = -0.1$, $\varepsilon^{fm} = -0.15$, $\eta = 0.4$									
TRA86	0.00	0.12	0.30	-0.47	0.42	-0.05	-0.14	7.20	0.99
OBRA93*	-0.02	-0.03	-0.20	0.01	-0.25	-0.25	-0.07	0.27	0.53
EGTRRA01	0.00	0.08	0.27	-0.30	0.35	0.05	0.06	7.19	1.01
TCJA17	0.00	0.12	0.38	-0.37	0.49	0.12	0.13	6.58	1.02
“High-Elasticity” Parameterization: $\varepsilon^m = 0.1$, $\varepsilon^f = 0.2$, $\varepsilon^{mf} = -0.1$, $\varepsilon^{fm} = -0.15$, $\eta = 0.8$									
TRA86	0.39	0.24	0.60	-0.47	1.23	0.75	0.57	7.20	1.12
OBRA93	-0.02	-0.03	-0.20	0.04	-0.25	-0.21	-0.22	0.27	0.57
EGTRRA01	0.18	0.16	0.54	-0.30	0.88	0.57	0.54	7.19	1.09
TCJA17	0.19	0.23	0.76	-0.37	1.18	0.81	0.76	6.58	1.14
“Low-Elasticity” Parameterization: $\varepsilon^m = 0$, $\varepsilon^f = 0.1$, $\varepsilon^{mf} = 0$, $\varepsilon^{fm} = -0.05$, $\eta = 0.4$									
TRA86	0.00	0.12	0.30	-0.08	0.42	0.34	0.32	7.20	1.05
OBRA93	0.00	-0.01	-0.10	0.01	-0.12	-0.11	-0.11	0.27	0.72
EGTRRA01	0.00	0.08	0.27	-0.04	0.35	0.31	0.29	7.19	1.05
TCJA17	0.00	0.12	0.38	-0.06	0.49	0.44	0.40	6.58	1.07
Baseline Parameterization + Participation Elasticity Varies by Income Quintile									
TRA86	0.19	0.18	0.23	-0.27	0.61	0.33	-	7.21	1.05
OBRA93	-0.01	-0.02	-0.21	0.03	-0.24	-0.21	-	0.27	0.56
EGTRRA01	0.09	0.12	0.28	-0.17	0.49	0.32	-	7.19	1.05
TCJA17	0.10	0.17	0.34	-0.22	0.61	0.39	-	6.58	1.06

Notes: Welfare gains are calculated using (2.30) taken with the negative sign. The pre-reform tax rates and reform-induces changes in tax rates are calculated using NBER TAXSIM applied to the ASEC CPS data. Column (5) shows total welfare gains when the cross-effects are ignored, and calculated as $(1) + (2) + (3)$. Column (6) shows total welfare gains, and calculated as $(4) + (5)$. Column (7) shows the welfare gains in a representative-couple economy. Column (9) is calculated as $(8)/[(8) - (6)]$, where (8) is the decrease in tax liabilities as a share of labor income before behavioral responses. In the last panel, the participation elasticity takes values 1/0.8/0.6/0.4/0.2 for the bottom/second/third/fourth/top couple’s income quintiles, keeping the mean participation elasticity equal to 0.6.
* Since the OBRA 1993 increased or left unchanged the tax rates for most spouses in the sample, I use the parameters from the “lower-bound” scenario in the panel corresponding to the “upper-bound” scenario and vice-versa.

the welfare gains range from -0.07 to 1.15 percent of aggregate labor income. Next, I consider the opposite scenario, namely, the “lower-bound” parameterization of elasticities. I flipped the values and assume low own elasticities and high cross-elasticities for the TRA 1986, the EGTRRA 2001, and TCJA 2017 reforms, and vice versa for the OBRA 1993. In this case, the welfare gains range from -0.25 to 0.12 percent of aggregate labor income. Overall, the first two panels of Table 2.2 can inform us about the bounds on efficiency gains resulting from the U.S. tax reforms.

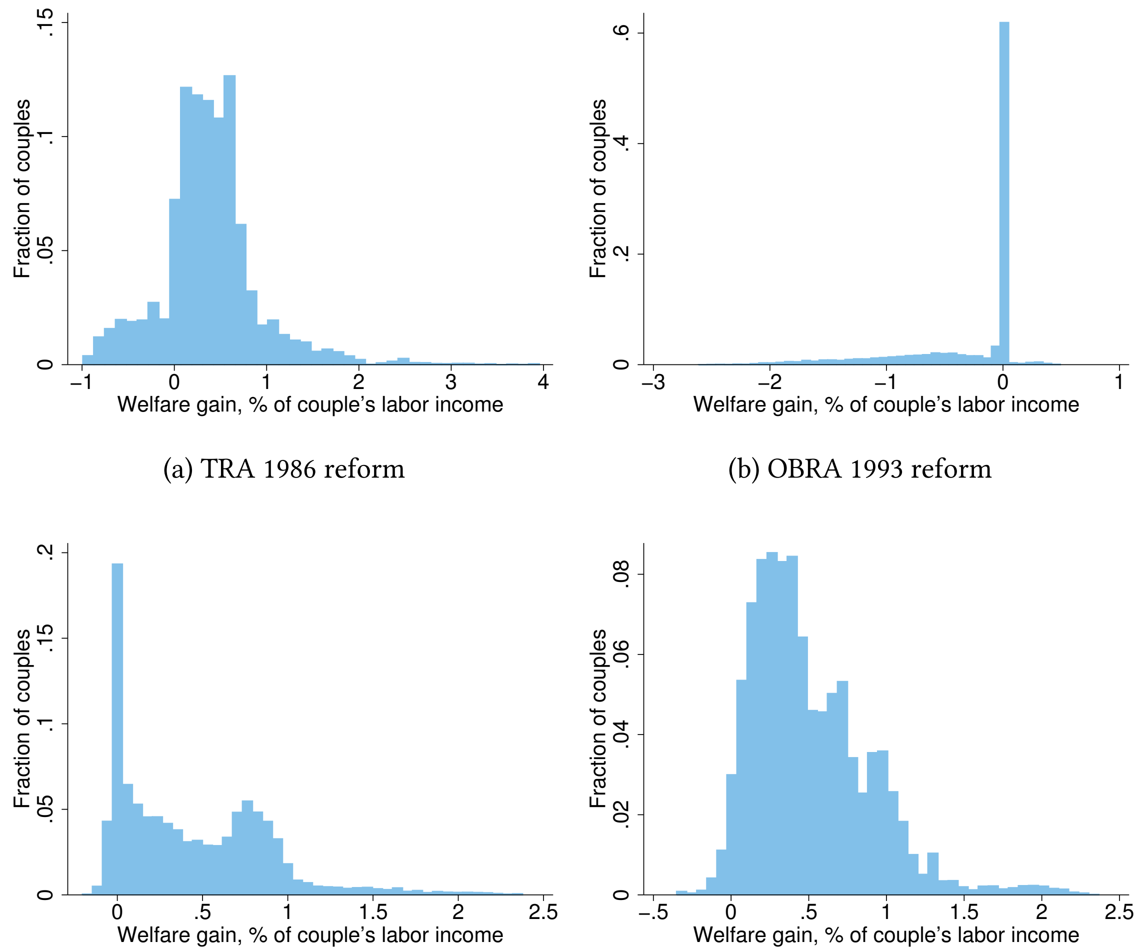
Next, I consider two parameterizations labeled as "high-elasticity" and "low-elasticity". In particular, I set all the elasticities to high values in the former case, and low values in the latter case. The third and fourth panels of Table 2.2 may facilitate the comparison of reforms that were conducted in different time periods. If married women's elasticities shrank between the 1970s and 2000s (Blau and Kahn, 2007; Heim, 2007), then the conclusion from Table 2.1 that the TCJA 2017 reform created the largest efficiency gains among four reforms may be reconsidered.

Finally, in the bottom panel of Table 2.2, I report the results of an exercise where I allow the participation elasticity to decline in household income. In particular, I assign values 1/0.8/0.6/0.4/0.2 to the first/second/third/fourth/fifth income quintiles, keeping the mean participation elasticity equal to 0.6. Under this parameterization, total efficiency gains range from -0.21 to 0.39 percent of aggregate labor income. These numbers are lower than in the baseline scenario because high-income couples have smaller participation elasticities and hence benefit less from tax reductions. In turn, low-income couples benefit more, but the aggregate measure of efficiency gains masks heterogeneity in welfare effects. Beyond all these findings, the results from Table 2.2 reinforce my claim that cross-elasticities and participation elasticities quantitatively important and should be accounted for in the welfare analysis of economic policies.

2.5.3 Welfare Gains Distribution

So far I consider the aggregate welfare effects of tax reforms, however the use of microdata combined with TAXSIM allows studying the distribution of welfare gains and losses. Indeed, the aggregate effects may mask significant heterogeneity across households.[31] In this section, I use the baseline parameterization of elasticities and answer the following questions. How are the efficiency gains from tax reforms distributed in the population of married couples? Furthermore, according to Table 2.1, three reforms created aggregate welfare gains. Are there any losers? Finally, how do the welfare gains vary by income?

[31] Using the U.S. data, Zidar (2019) finds that the positive relationship between tax cuts and employment growth is largely driven by tax cuts for low-income group, rather than high-income individuals.



(a) TRA 1986 reform

(b) OBRA 1993 reform

(c) EGTRRA 2001 reform

(d) TCJA 2017 reform

Figure 2.3: Distribution of Reform-Induced Welfare Gains Among Couples

NOTES: Welfare gains are calculated under a baseline parameterization of elasticities.

Figure 2.3 documents the distribution of welfare gains among couples for each reform. A simple visual inspection confirms the argument that income tax changes create heterogeneous welfare effects, and there are both winners and losers from each reform. In Table 2.3, I report the percentiles of efficiency gains distribution. For the TRA 1986, the median welfare gain is equal to 0.37 percent of couple's labor income. While a substantial fraction of couples win from the reform, those at the 10th percentile experience welfare loss equal to 0.21 percent of the labor income. On the contrary, couples at the 90th percentile receive welfare gain of 0.94 percent of labor income. Next, following the OBRA 1993, the median couple stay welfare neutral. However, couples at the 10th percentile experience

Table 2.3: Distribution of Welfare Gains for Couples, % of Couple's Labor Income

Reform	P10	P25	P50	P75	P90
TRA86	-0.21	0.13	0.37	0.61	0.94
OBRA93	-1.09	-0.40	0.00	0.00	0.00
EGTRRA01	0.00	0.06	0.36	0.76	0.95
TCJA17	0.10	0.23	0.42	0.74	1.02

Notes: Welfare gains are calculated under a baseline parameterization of elasticities, and are measured as a share of couple's labor income.

welfare loss of 1.09 percent of labor income. In the case of the other two reforms, the EGTRRA 2001 and the TCJA 2017, the values corresponding to the 10th percentile are non-negative. One more observation that follows from Figure 2.3 and Table 2.3 is that the dispersion of the efficiency gains significantly differs across the reforms. Apart from the OBRA 1993, where most of couples are welfare neutral, the P75-P25 ratio for the TRA 1986, the EGTRRA 2001, and the TCJA 2017 is equal to 4.7, 12.7, and 3.2 correspondingly.

Next, in Table 2.4, I report the fractions of winners, losers, and welfare-neutral couples. I define winners as those with welfare gains above 0.1 percent of couple's labor income. Losers are defined as those with welfare losses greater than 0.1 percent of labor income. Finally, welfare-neutral couples are those whose absolute values of welfare gains or losses do not exceed 0.1 percent of labor income. It follows that, despite the TRA 1986 created aggregate welfare gains, it left 12.3 percent of couples with welfare losses. In turn, while the OBRA 1993 created aggregate welfare losses, for about two-thirds of the married couples this reform was welfare-neutral. In the case of EGTRRA 2001 and the TCJA 2017 the share of winners is equal to 69.6 and 90.3 percent correspondingly.

Finally, in Figure 2.4, I explore how the welfare gains vary by income. Each dot represents 5 percent of the sample, and the grey shaded areas represent the interval between "lower-bound" and "upper-bound" elasticity parameterizations. Figure 2.4 clearly shows that efficiency gains change nonlinearly with income. There are two general patterns. First, the TRA 1986, the OBRA 1993 (excluding the bottom 10 percent), and the TCJA 2017 can be characterized as monotonic tax reforms (Bierbrauer et al., 2021) and they resulted in monotonic relationships between welfare gains and income. Overall, richer taxpayers benefited from these reforms more than poorer taxpayers. Second, the OBRA 1993

Table 2.4: Fractions of Winners, Losers, and Welfare-Neutral Couples

Reform	Winners, %	Losers, %	Neutral, %
TRA86	78.7	12.3	9.1
OBRA93	1.4	31.2	67.4
EGTRRA01	69.6	0.3	30.1
TCJA17	90.3	0.6	9.0

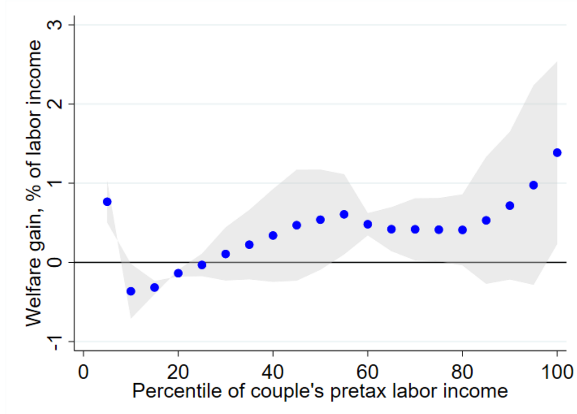
NOTES: Welfare gains are calculated under a baseline parameterization of elasticities. Winners are defined as couples with welfare gains above 0.1 percent of couple's labor income. Losers are defined as couples with welfare losses greater than 0.1 percent of labor income. Welfare-neutral couples are defined as those whose absolute values of welfare gains or losses do not exceed 0.1 percent of labor income.

and the EGTRRA 2001 reforms demonstrate a U-shaped pattern in the welfare gains. In this case, the main winners of the reforms are located at the lower and upper ends of the income distribution. Interestingly, Hotchkiss et al. (2012) and Hotchkiss et al. (2021) discover similar patterns of the welfare gains despite using very different methodology. Overall, the results from this section reassure that despite a representative couple model can be a reasonable candidate for assessing aggregate efficiency gains, it does not capture rich heterogeneity and misses important distributional aspects of tax reforms.

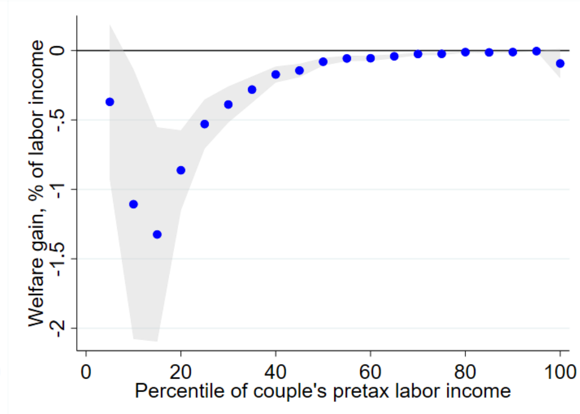
2.5.4 Counterfactual Tax Reforms

In this section, I conduct two sets of counterfactual tax reforms aimed at addressing the following questions. First, how does the pre-reform income distribution matter for my results? Second, how do the initial conditions—pre-reform income distribution and tax law—jointly matter for the estimates of welfare gains?

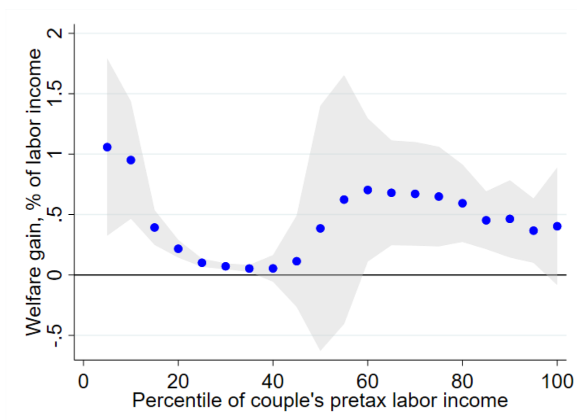
In Table 2.5, I report the results for the first set of counterfactual reforms. In this exercise, I take the couples' income distribution in pre-reform year t (for example, in 1986), and apply the pre- and post-reform X's (for example, the TCJA 2017) tax laws. Table 2.5 consists of four panels, where each panel represents the income distribution that I use. For example, Panel A shows the results for four reforms applied to the 1986 income distribution. The first column displays the reforms. Column (9) reports the percentage difference between counterfactual and actual welfare gains per dollar spent, shown in column (8). By construction, the results in the first line of Panel A coincide with one from Table 2.1, and hence there is zero in column (9). The results from the bottom line of Panel A



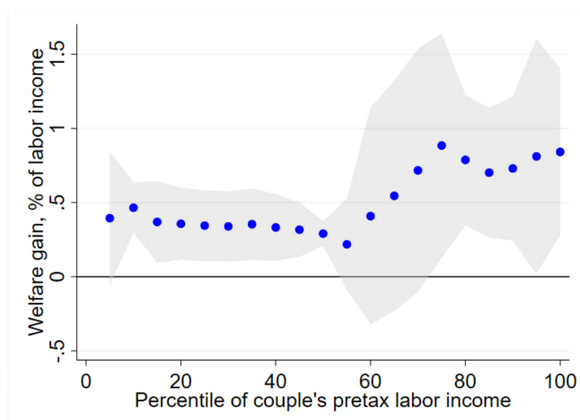
(a) TRA 1986 reform



(b) OBRA 1993 reform



(c) EGTRRA 2001 reform



(d) TCJA 2017 reform

Figure 2.4: Welfare Gains and Income Distribution, Couples

Notes: Welfare gains are measured as a percentage of the labor income. Each dot represents 5 percent of the sample. The grey shaded area represents the interval between "lower-bound" and "upper-bound" elasticity parameterizations.

should be interpreted in the following way: if the TCJA 2017 were to be applied to the 1986 income distribution, total welfare gains would be 0.40 percent of aggregate labor income. It follows from column (9) that this counterfactual 2017 TCJA reform would deliver 2.68% less welfare gain per dollar spent than the actual TCJA 2017 (reported in the bottom line of Panel D). In turn, the first line of Panel D shows that if the TRA 1986 reform were to be applied to the 2017 income distribution, then the welfare gain per dollar spent would be 5.48% higher than from the actual TRA 1986. Overall, the results from Table 2.5 suggest that despite the initial income distribution matters, it has limited quantitative importance. Counterfactual welfare gains per dollar spent do not differ by more than 7.54% from the

Table 2.5: Welfare Effects of Tax Reforms Applied to Counterfactual Income Distribution

Reform	Welfare gain, % of aggregate labor income						Tax Liab. Reduc., %	Δ Welfare/ $ Spent	Diff., %
	Intensive Males	Intensive Females	Extensive Females	Cross-Effects	Total	RC			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Tax Reforms Applied to Pre-TRA86 Distribution of Couples									
TRA86	0.19	0.18	0.45	-0.27	0.55	0.44	7.20	1.08	0.00
OBRA93	-0.01	-0.02	-0.13	0.02	-0.14	-0.14	0.29	0.68	+7.54
EGTRRA01	0.09	0.11	0.36	-0.16	0.40	0.37	7.46	1.06	-0.80
TCJA17	0.09	0.12	0.36	-0.18	0.40	0.37	5.76	1.07	-2.68
Panel B: Tax Reforms Applied to Pre-OBRA93 Distribution of Couples									
TRA86	0.19	0.22	0.53	-0.30	0.63	0.51	7.38	1.09	+1.09
OBRA93	-0.01	-0.02	-0.15	0.03	-0.16	-0.16	0.27	0.63	0.00
EGTRRA01	0.08	0.12	0.39	-0.16	0.43	0.40	7.38	1.06	-0.32
TCJA17	0.09	0.14	0.41	-0.18	0.45	0.42	5.87	1.08	-1.88
Panel C: Tax Reforms Applied to Pre-EGTRRA01 Distribution of Couples									
TRA86	0.33	0.31	0.82	-0.48	0.97	0.76	10.23	1.11	+2.11
OBRA93	-0.04	-0.04	-0.18	0.07	-0.19	-0.20	-0.97		
EGTRRA01	0.09	0.12	0.40	-0.17	0.44	0.42	7.19	1.07	0.00
TCJA17	0.10	0.14	0.44	-0.20	0.48	0.45	6.19	1.08	-1.80
Panel D: Tax Reforms Applied to Pre-TCJA17 Distribution of Couples									
TRA86	0.29	0.42	1.13	-0.52	1.32	1.05	10.62	1.14	+5.48
OBRA93	-0.03	-0.05	-0.22	0.07	-0.24	-0.25	-0.96		
EGTRRA01	0.08	0.13	0.48	-0.17	0.52	0.49	7.15	1.08	+1.18
TCJA17	0.10	0.17	0.57	-0.22	0.62	0.58	6.58	1.10	0.00

NOTES: Welfare gains are calculated using (2.30) taken with the negative sign and under a baseline parameterization of elasticities. In each exercise, I take the distribution of couples corresponding to some pre-reform year, as indicated in four panels, and calculate the welfare effects from applying the reform that is shown in the left-most column. Column (5) shows total welfare gains, and calculated as $(1)+(2)+(3)+(4)$. Column (6) shows the welfare gains in a representative-couple economy. Column (8) is calculated as $(7)/[(7)-(5)]$, where (7) is the decrease in tax liabilities as a share of labor income before behavioral responses. Column (9) shows the percentage difference relative to the actual welfare gains from the reform.

actual ones.

Next, I conduct a set of counterfactual reforms, where I take the distribution of couples and the tax law corresponding to some pre-reform year t (for example, in 1986) and apply the post-reform X's (for example, the TCJA 2017) tax law. In other words, in this example, I study the welfare consequences of moving from the pre-TRA 1986 economy to the post-TCJA 2017 economy. Table 2.6 reports the results. I do not conduct the backward reforms between two consecutive reforms (e.g., I do not consider the welfare consequences of moving from the pre-OBRA 1993 economy to the post-TRA 1986 economy) because the welfare effects are likely to be negligible in these cases. Panel A suggests two interesting findings. First, moving from the pre-TRA 1986 economy to the post-EGTRRA 2001 and post-TCJA 2017 economies leads to substantial reduction in tax liabilities, 17.85 and 22.28 percent, relative to the actual TRA 1986 reform (7.20 percent), and higher efficiency gains, 0.88 and 1.19 percent of aggregate labor income (the actual TRA 1986 results in 0.55 per-

Table 2.6: Welfare Effects of Counterfactual Tax Reforms

Reform	Welfare gain, % of aggregate labor income							
	Intensive Males	Intensive Females	Extensive Females	Cross-Effects	Total	RC	Tax Liab. Reduc., %	Δ Welfare/ $ Spent
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Tax Reforms Applied to Pre-TRA86 Distribution of Couples and Tax Law								
TRA86	0.19	0.18	0.45	-0.27	0.55	0.44	7.20	1.08
OBRA93	0.19	0.17	0.35	-0.27	0.44	0.29	7.73	1.06
EGTRRA01	0.27	0.27	0.75	-0.41	0.88	0.74	17.85	1.05
TCJA17	0.36	0.38	1.02	-0.58	1.19	0.96	22.28	1.06
Panel B: Tax Reforms Applied to Pre-OBRA93 Distribution of Couples and Tax Law								
TRA86	—	—	—	—	—	—	—	—
OBRA93	-0.01	-0.02	-0.15	0.03	-0.16	-0.16	0.27	0.63
EGTRRA01	0.06	0.09	0.26	-0.12	0.29	0.27	10.09	1.03
TCJA17	0.13	0.19	0.51	-0.25	0.57	0.52	14.69	1.04
Panel C: Tax Reforms Applied to Pre-EGTRRA01 Distribution of Couples and Tax Law								
TRA86	0.09	0.08	0.25	-0.15	0.27	0.22	-0.74	
OBRA93	—	—	—	—	—	—	—	—
EGTRRA01	0.09	0.12	0.40	-0.17	0.44	0.42	7.19	1.07
TCJA17	0.15	0.23	0.69	-0.31	0.76	0.70	12.16	1.07
Panel D: Tax Reforms Applied to Pre-TCJA17 Distribution of Couples and Tax Law								
TRA86	0.03	0.02	0.05	-0.05	0.05	-0.02	-6.40	
OBRA93	-0.03	-0.06	-0.26	0.07	-0.27	-0.29	-7.38	
EGTRRA01	—	—	—	—	—	—	—	—
TCJA17	0.10	0.17	0.57	-0.22	0.62	0.58	6.58	1.10

NOTES: Welfare gains are calculated using (2.30) taken with the negative sign and under a baseline parameterization of elasticities. In each exercise, I take the distribution of couples and the tax law corresponding to some pre-reform year, as indicated in four panels, and calculate the welfare effects from applying the reform that is shown in the left-most column. Column (5) shows total welfare gains, and calculated as $(1) + (2) + (3) + (4)$. Column (6) shows the welfare gains in a representative-couple economy. Column (8) is calculated as $(7)/[(7) - (5)]$, where (7) is the decrease in tax liabilities as a share of labor income before behavioral responses.

cent of aggregate labor income). However, when I make the efficiency gains comparable, column (8) shows that the actual TRA 1986 generated more welfare gain per dollar spent than the alternative considered counterfactual reforms.

2.6 Efficiency Loss and Nonlinear Taxation of Couples

2.6.1 Linearization Bias

The framework in Section 2.2 is elaborated under linear tax and transfer function. Despite the real tax and transfer schedules often feature nonlinearities, this assumption is widely used in the literature studying the efficiency gains of tax reforms (Chetty, 2009). How sizable is the bias in the estimates of welfare gains resulting from the linearity assumption? In this section, I address this question by extending the framework of Blomquist and Simula (2019), who study linearization bias through the lens of the model with singles, to the setting with couples.

I use a version of the model from Section 2.2. In particular, consider an economy populated by couples with preferences $v(c, y_m, y_f, \upsilon_m, \upsilon_f)$ where y_m and y_f are taxable incomes of a male and a female, υ_m and υ_f are idiosyncratic preference parameters jointly drawn from continuous distribution Γ. To focus on the bias that comes from tax function linearization, I abstract from the labor force participation margin and consider an economy populated by dual-earner couples, i.e. in all couples both spouses are employed. Furthermore, I state the problem in terms of taxable rather than labor income.[32] The couple's budget constraint is given by $c = y_m + y_f - T(y_m, y_f, \theta) + I$ where I is lump-sum non-taxable income. Following the similar steps as in Section 2.2, I obtain the expression for marginal deadweight loss, $dD/d\theta$.

Now suppose that the original tax and transfer function T is replaced by a linearized function T^L that delivers the same solution as the original problem, $\left(c^*, y_m^*, y_f^*\right)$. In particular, the latter is described by proportional tax rates $\tau_m = \partial T(y_m, y_f, \theta)/\partial y_m$ and $\tau_f = \partial T(y_m, y_f, \theta)/\partial y_f$ and a lump-sum component. Namely,

$$T^L(y_m, y_f, \tau_m, \tau_f) = \tau_m(\theta) y_m + \tau_f(\theta) y_f + T^* \tag{2.34}$$

where I set $T^* = y_m^* + y_f^* - c^* - \tau_m y_m^* + \tau_f y_f^* + I$. Again, following the steps from Section 2.2 and using the linearized budget constraint (2.34), I obtain the expression for marginal deadweight loss, $dD^L/d\theta$.

How does the original reform-induced efficiency loss, $dD/d\theta$, differ from the change in efficiency loss under a linearized tax and transfer function, $dD^L/d\theta$? Proposition 2.2 characterizes these objects and reveals that they depend on two sets of terms, utility curvature and tax function curvature. In particular, from binding $v(c, y_m, y_f, \upsilon_m, \upsilon_f) = \bar{U}$, obtain the inverse, $c = \psi\left(y_m, y_f, \upsilon_m, \upsilon_f, \bar{U}\right)$. Next, denote $\psi''_{ij} \equiv \partial^2\psi(\cdot)/\partial\tilde{y}_i\partial\tilde{y}_j$, $T''_{ij} \equiv$

[32] Feldstein (1999) suggests that the relevant statistic for calculating efficiency loss is the elasticity of taxable income because people can adjust their behavior along different margins, not only labor supply.

$\partial^2 T(\cdot)/\partial\tilde{y}_i\partial\tilde{y}_j$, $T''_{i\theta} \equiv \partial^2 T(\cdot)/\partial\tilde{y}_i\partial\theta$, and, finally, $T'_i \equiv \partial T(\cdot)/\partial y_i$. Then, ψ-terms account for utility curvature and T-terms account for tax function curvature.

Proposition 2.2 (Efficiency Loss under Nonlinear Taxation of Couples). *Under nonlinear tax function T, efficiency loss from any arbitrary small tax reform $d\theta \approx 0$ is given by*

$$\frac{dD}{d\theta} = -\int \left[\frac{T'_m \left[\left(\psi''_{mf} + T''_{mf}\right) T''_{f\theta} - \left(\psi''_{ff} + T''_{ff}\right) T''_{m\theta} \right]}{\left(\psi''_{mm} + T''_{mm}\right)\left(\psi''_{ff} + T''_{ff}\right) - \left(\psi''_{mf} + T''_{mf}\right)^2} + \frac{T'_f \left[\left(\psi''_{mf} + T''_{mf}\right) T''_{m\theta} - \left(\psi''_{mm} + T''_{mm}\right) T''_{f\theta} \right]}{\left(\psi''_{mm} + T''_{mm}\right)\left(\psi''_{ff} + T''_{ff}\right) - \left(\psi''_{mf} + T''_{mf}\right)^2} \right] d\Gamma\left(\upsilon_m, \upsilon_f\right) \quad (2.35)$$

Under linearized tax function T^L, efficiency loss from any arbitrary small tax reform $d\theta \approx 0$ is given by

$$\frac{dD^L}{d\theta} = -\int \left[\frac{T'_m \left(\psi''_{mf} T''_{f\theta} - \psi''_{ff} T''_{m\theta}\right)}{\psi''_{mm}\psi''_{ff} - \left(\psi''_{mf}\right)^2} + \frac{T'_f \left(\psi''_{mf} T''_{m\theta} - \psi''_{mm} T''_{f\theta}\right)}{\psi''_{mm}\psi''_{ff} - \left(\psi''_{mf}\right)^2} \right] d\Gamma\left(\upsilon_m, \upsilon_f\right) \quad (2.36)$$

Proof. *See Appendix B.1.2.*

To obtain (2.36) from (2.35), one should simply set $T''_{mm} = T''_{ff} = T''_{mf} = 0$. Expressions (2.35) and (2.36) are generalized versions of equations (5) and (8) from Blomquist and Simula (2019) who derive them for the economy populated by singles. To demonstrate that their result is a special case of Proposition 2.2, set to zero all joint terms, $\psi''_{mf} = T''_{mf} = 0$, in (2.35), and then marginal deadweight loss for individual of gender j is given by $T'_j T''_{j\theta} / \left(\psi''_{jj} + T''_{jj}\right)$, and this is (5) in Blomquist and Simula (2019). The linearized version (2.36) is given by $T'_j T''_{j\theta}/\psi''_{jj}$, and this is (8) in their paper.

Define the *linearization bias* as the percentage difference between reform-induced efficiency loss under linearized and original tax and transfer functions:

$$\Delta = \frac{\frac{dD^L}{d\theta} - \frac{dD}{d\theta}}{\frac{dD}{d\theta}} \quad (2.37)$$

While Proposition 2.2 suggests that the size of this bias is affected by the curvatures of utility and tax function, it is instructive to assume the functional forms for utility v and tax and transfer function T and obtain the expression for Δ in terms of model parameters.

2.6.2 Efficiency Loss and HSV Tax Function

I assume that the couple's preferences are given by

$$v\left(c, y_m, y_f, \upsilon_m, \upsilon_f\right) = c - \frac{\upsilon_m}{\sigma+1}\left(\frac{y_m}{\upsilon_m}\right)^{\sigma+1} - \frac{\upsilon_f}{\sigma+1}\left(\frac{y_f}{\upsilon_f}\right)^{\sigma+1} \tag{2.38}$$

where parameter σ is the inverse elasticity of taxable income. The quasilinearity assumption implies that there is no income effect, and hence the compensated and uncompensated taxable income functions coincide. Furthermore, υ_m and υ_f may be interpreted as wages.

Next, I choose the functional form for T to summarize the tax and transfer system in a simplified way. Heathcote et al. (2017) show that the log-linear function $T(y) = y - \lambda y^{1-\theta}$ (henceforth, HSV tax function) yields a remarkably good approximation of the actual tax and transfer system in the United States. In this specification, parameter θ is interpreted as a measure of tax progressivity, and parameter λ determines the level of tax rates. To capture joint and separate taxation of spousal incomes, I consider the following tax and transfer functions (Bick and Fuchs-Schündeln, 2017b; Borella et al., 2021):

$$T\left(y_m, y_f\right) = \lambda\left(y_m + y_f\right)^{1-\theta} \tag{2.39}$$

$$T\left(y_m, y_f\right) = \tilde{\lambda} y_m^{1-\theta} + \tilde{\lambda} y_f^{1-\theta} \tag{2.40}$$

Function (2.39) describes joint taxation, while function (2.40) describes separate taxation. To close the model, I assume that the government uses all tax revenue to fund the government expenditures, and runs a balanced budget. Denote by g the share of government consumption in aggregate income. Finally, I set lump-sum non-taxable income of couples to zero, $I = 0$.

I consider a small reform that changes progressivity of the tax and transfer system, $d\theta \approx 0$. How sizable is the linearization bias? Proposition 2.3 states that it is given by the ratio between the tax progressivity parameter θ and the inverse elasticity of taxable income σ. Hence, the magnitude of the bias is jointly determined by a policy parameter (tax function curvature) and a preference parameter (utility curvature).

Proposition 2.3 (Linearization Bias with HSV Tax Function). *Consider a small reform that changes tax progressivity, $d\theta \approx 0$. Under both joint and separate taxation of spousal incomes, the linearization bias is given by*

$$\Delta = \frac{\theta}{\sigma} \tag{2.41}$$

Proof. *See Appendix B.1.4.*

Higher initial progressivity of the tax system and higher elasticity of taxable income result in the greater magnitude of the linearization bias or, alternatively, greater overestimation of aggregate efficiency gain. Using (2.41) and estimates of θ and σ from the literature, I can quantify Δ. Using the information on 1720 estimates of the elasticity of taxable income from 61 papers, Neisser (2021) report that the majority lies between 0 and 1 with a peak around 0.3 and an excess mass between 0.7 and 1. Next, Heathcote et al. (2017), using the sample of the U.S. households aged 25-60, where at least one adult has strong labor market attachment, and the time period between 2000 and 2006, estimate $\theta = 0.181$. Hence, for the range of taxable income elasticities between 0.2 and 0.8 (hence, between $\sigma = 5$ and $\sigma = 1.25$), the size of the linearization bias varies between 3.6% (0.181/5 $\times$ 100%) and 18.1% (0.181/1 $\times$ 100%). In other words, aggregate efficiency gain from a tax reform is overestimated by 3.6-18.1%.

2.7 Conclusion

This paper develops a framework to study the welfare effects of income tax changes on married couples. I build a static model of couples' labor supply that accounts for the presence of both intensive and extensive margins. My main result is an expression for efficiency gains, resulting from any arbitrary small tax reform, as a function of (i) labor supply elasticities capturing the behavioral responses to the tax policy reforms, (ii) pre-reform tax rates and reform-induced changes in the tax rates, and (iii) labor income shares. This formula allows to transparently decompose welfare gains into the effects that operate through the spousal own working hours, spousal cross-effects of working hours, and the women's participation margin.

At the next step, I use this expression to quantify the welfare effects of the labor income tax changes induced by four tax reforms implemented in the United States: the Tax Reform Act of 1986, the Omnibus Budget Reconciliation Act of 1993, the Economic Growth and Tax Relief Reconciliation Act of 2001, and the Tax Cuts and Jobs Act of 2017. To parameterize the model, I use the CPS ASEC data combined with the NBER TAXSIM calculator. My baseline estimates suggest that these reforms created welfare gains ranging from -0.16 to 0.62 percent of aggregate labor income. Looking at the forces that shape the efficiency gains, I find that, first, the bulk of the gains is generated by the women's labor force participation responses, and, second, the spousal cross-effects of working hours are quantitatively important, and abstracting from them leads to an overestimation of the welfare effects. Although three out of four considered U.S. tax reforms delivered aggregate welfare gains, I show that this result masks significant heterogeneity. In fact, each reform created both winners and losers. Furthermore, the welfare gains are unequally distributed among the couples with different incomes.

Finally, I show the robustness of my findings to several possible caveats. In the first set of exercises, I consider alternative parameterizations of elasticities. It partially allows addressing the concerns about the sensitivity of the results to the choice of values of elasticities. Next, I conduct a set of counterfactual reforms aimed at addressing the concerns about the sensitivity of results to the initial income distribution and the levels of pre-reform tax rates. Furthermore, I address the concern about the biased estimates of welfare effects resulting from the assumption about linearity of the tax and transfer function. To do so, I characterize the linearization bias under the log-linear tax function that approximates the tax and transfer system in the United States. Assuming a small reform that translates into a change in tax progressivity, I show that the linearization bias is given by the ratio between the tax progressivity parameter and the inverse elasticity of taxable income. Existing estimates of these objects suggest that the size of this upward bias lies within the range of 3.6-18.1%.

Chapter 3

Simulation of Coronavirus Disease 2019 Scenarios with Possibility of Reinfection

3.1 Introduction

The rapid spread of coronavirus disease 2019 (COVID-19) created significant challenges for economies and healthcare systems of many countries around the world. The situation evolved extremely quickly and, in early 2020, there was a high degree of uncertainty about the future outcomes of the pandemic. As of September 1, 2020, there have been 25.9 million confirmed cases globally, including about 860 thousand deaths (Worldometers, 2020).[33]

One of the crucial questions that had no definite answer was whether people who recovered from COVID-19 could be reinfected with the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The case reports were scarce — there were a few of them about positive testing after recovering from COVID-19 in China, Japan, and South Korea — and it was not clear whether these patients were truly reinfected or not. Shi et al. (2020) discuss the immune responses induced by COVID-19. Another study, Bao et al. (2020), using the sample of four rhesus macaques, conclude that the primary SARS-CoV-2 infection could protect from subsequent reinfections. In turn, An et al. (2020), show that 38 out of 262 patients, i.e. 14.5 percent, recovered from COVID-19, tested positive for SARS-CoV-2, using polymerase chain reaction (PCR) tests, after being discharged from the hospital in Shenzhen. Those patients did not show obviously clinical symptoms and disease progression upon readmission. A study by To et al. (2021) shows the results of the whole genome sequencing that was performed directly on respiratory specimens collected during two episodes of COVID-19 in a patient. Epidemiological, clinical, serological, and genomic analyses confirmed that the patient had reinfection instead of persistent viral shedding from the first infection. Their paper suggests that SARS-CoV-2 may continue to

[33] This paper was published in October 2020.

circulate among the human populations despite herd immunity due to natural infection or vaccination.

In the absence of a clear answer about the risk of reinfection with the new coronavirus, it is instructive to be aware of the possible scenarios. This study aims at providing the attempt in this direction.[34] I use a Susceptible-Exposed-Infectious-Resistant-Susceptible (SEIRS) model that differs from a standard SEIR model, considered in Hethcote (2000) and Chowell et al. (2004), and, in application to COVID-19, Kucharski et al. (2020), Lin et al. (2020), Prem et al. (2020), and Wang et al. (2020), among others, with an additional assumption that recovered individuals can become susceptible to infection again. In methodologically related papers, Reynolds et al. (2014) and Etbaigha et al. (2018) study the reinfection of swines with influenza A virus (IAV). The simulations considered in this paper are by no means the definitive quantitative forecasts. Instead, the purpose is to show the patterns of the disease dynamics if people can be reinfected with the new coronavirus. In fact, the risk of reinfection would definitely affect the scope and duration of policies that are currently in place.

I consider three different ways of modeling reinfection. I begin with the model where individuals have constant immunity waning rate and study the effects of the mitigation policies captured by the changes in the transmission rate and hence the reproduction number. The basic reproduction number, R_0, is a crucial parameter for evaluation the spread of the infection and the effects of mitigation measures. Existing estimates for COVID-19 suggest that R_0 is between 2 and 6. Using the data from Wuhan, China, Wu et al. (2020) estimate R_0 to be 2.68 (95% confidence interval (CI): 2.47-2.86). Using the data from mainland China, Zhao et al. (2020) conclude that the mean estimate of R_0 ranges from 2.24 (95% CI: 1.96-2.55) to 3.58 (95% CI: 2.89-4.39). Using the data for Italy, Remuzzi and Remuzzi (2020) propose R_0 to be in the range 2.76-3.25. Using the data for Japan, Kuniya (2020) estimates R_0 to be 2.6 (95% CI: 2.4-2.8). Fauci et al. (2020) propose R_0 to be 2.2. Sanche et al. (2020) obtain a higher median estimate, $R_0 = 5.7$ (95% CI: 3.8-8.9). Beyond that, Korolev (2021) shows that estimates of R_0 are highly sensitive to the values of epidemiologic

[34] Giannitsarou et al. (2021) and Çenesiz and Guimarães (2022) are the other papers that consider the possibility of waning immunity, however, they were published after the current study.

parameters. In the simulations, I consider the range of values of the basic reproduction number.

Crucially, in each model experiment I consider not only how different are the reinfection and no-reinfection scenarios, but also how the mitigation measures affect this difference. To check the robustness of my findings about the role of the mitigation measures with and without reinfection, I turn to the alternative modeling assumptions about reinfection. First, I assume that individuals, once being reinfected, have a milder form of the disease. Second, instead of a constant immunity waning rate, I assume that the individuals that are resistant at some date (those who were infected in the past) become susceptible again. The conceptual framework that I use can be easily incorporated into more complex models in future studies.

3.2 Model

Consider a SEIRS model with constant population N normalized to one. Each period of time, the population consists of four classes: susceptible (S), exposed (E), infected (I), and resistant (recovered) (R):

$$S(t) + E(t) + I(t) + R(t) = N, \quad \forall t \geq 0 \tag{3.1}$$

Since $N = 1$, variables S, E, I, and R correspond to the fractions of the population. I assume that recovered individuals can become susceptible to infection again at rate ω. The compartmental model is formulated by the following set of ordinary differential equations:

$$\frac{dS(t)}{dt} = -\beta(t)\frac{S(t)}{N}I(t) + \omega R(t) \tag{3.2}$$

$$\frac{dE(t)}{dt} = \beta(t)\frac{S(t)}{N}I(t) - \sigma E(t) \tag{3.3}$$

$$\frac{dI(t)}{dt} = \sigma E(t) - \gamma I(t) \tag{3.4}$$

$$\frac{dR(t)}{dt} = \gamma I(t) - \omega R(t) \tag{3.5}$$

The transmission rate, $\beta(t)$, accounts for the rate at which infected individuals interact with others and transmit the disease and is given by

$$\beta(t) = \gamma \tilde{R}(t) \tag{3.6}$$

where $\tilde{R}(t)$ is the time-varying reproduction number. Absent mitigation measures, $\tilde{R}$ corresponds to the basic reproduction number, R_0. To simplify notation, here and thereafter I omit explicit dependence of $\tilde{R}$ on time whenever it does not cause confusion. The transmission rate, $\beta(t)$, captures the impact of all mitigation measures such as quarantine, travel restrictions, or social distancing. To study scenarios under different mitigation policies, I adapt a flexible functional form for the time-varying reproduction number. Following Atkeson (2020), I parameterize $\tilde{R}(t)$ as follows:

$$\tilde{R}_1(t) = \exp(-\eta_1 t)\tilde{R}_1(0) + (1 - \exp(-\eta_1 t))R_1^* \tag{3.7}$$

$$\tilde{R}_2(t) = \exp(-\eta_2 t)\tilde{R}_2(0) + (1 - \exp(-\eta_2 t))R_2^* \tag{3.8}$$

$$\tilde{R}(t) = \frac{1}{2}\left(\tilde{R}_1(t) + \tilde{R}_2(t)\right) \tag{3.9}$$

where $\tilde{R}_1(0)$ and $\tilde{R}_2(0)$ (R_1^* and R_2^*) are the initial (long-run) values for $\tilde{R}_1$ and $\tilde{R}_2$. Parameter η_1 determines the rate at which $\tilde{R}_1$ converges to R_1^*. In turn, parameter η_2 governs the rate at which $\tilde{R}_2$ converges to R_2^*. By appropriately choosing the parameter values, I can capture different scenarios of the mitigation policies. In particular, in the simulations in Section 3.3, I vary the speed of imposing the mitigation measures and also consider the scenario when extremely severe mitigation measures at the beginning of the pandemic are followed by their gradual relaxation. From (3.7)-(3.9), the dynamics of $\tilde{R}_1$, $\tilde{R}_2$, and $\tilde{R}$ is described by the following equations:

$$\frac{d\tilde{R}_1(t)}{dt} = -\eta_1(\tilde{R}_1(t) - R_1^*) \tag{3.10}$$

$$\frac{d\tilde{R}_2(t)}{dt} = -\eta_2(\tilde{R}_2(t) - R_2^*) \tag{3.11}$$

$$\frac{d\tilde{R}(t)}{dt} = -\frac{1}{2}\eta_1 \left(\tilde{R}_1(t) - R_1^*\right) - \frac{1}{2}\eta_2 \left(\tilde{R}_2(t) - R_2^*\right) \tag{3.12}$$

Parameters (σ, γ, ω) represent the characteristics of COVID-19 and assumed to be constant. For parameters σ and γ, I take the estimates from the literature. The parameter σ stands for the mean incubation period of the disease, and its estimates vary from 1/5.2 to 1/3, see Lin et al. (2020) and Wang et al. (2020). Following Li et al. (2020a) and Wang et al. (2020), I adopt a mean latent period of 5.2 days (infection rate, $\sigma = 1/5.2$). Next, I adopt a mean infectious period of 18 days (recovery rate, $\gamma = 1/18$) in line with Chen et al. (2020) and Wang et al. (2020). Parameter ω, the immunity waning rate, is of the main interest for this paper, and since, to date, there are no credible estimates of it, I consider the range of different values, $\omega \in \{0, 1/365, 1/183, 1/120, 1/60\}$. To et al. (2021) show that the second episode of asymptomatic infection occurred 142 days after the first symptomatic episode in an apparently immunocompetent patient. This period is consistent with considered range of ω. The case $\omega = 0$ corresponds to no reinfection. The value of ω is driven by immunity waning after the infection or the rate of virus mutation. Next, the initial values for actively infected and exposed population are taken for the United States and set to $I(0) = 1/1000$, i.e. 0.1 percent of the population, and $E(0) = 43.75 \times I(0)$ respectively. I use March 16-17, 2020 as the initial date (March 17, 2020 was a day at which the last U.S. state reported its first case, see Peirlinck et al. (2020)). I take $I(0) = 1/1000$ from Berger et al. (2022). Official data reports around 4500 cases in the United States on March 16, and they assume that this represents 1.5 percent of all cases. This rate of underreporting is derived by Hortaçsu et al. (2021) for March 9, 2020. $E(0) = 43.75 \times I(0)$ corresponds to the estimates for the United States by Peirlinck et al. (2020).

Throughout the simulations, I fully acknowledge that only a fraction of the model-generated cases are reported in reality. Li et al. (2020b) study the critical importance of undocumented COVID-19 cases for understanding the overall prevalence and pandemic potential of this disease. Lin et al. (2020) emphasize that the reporting rate is time-varying.

3.3 Model Simulations

In this section, I use the assumptions about the time paths for $\tilde{R}$ from Atkeson (2020). This allows me to clearly compare the outcomes under reinfection with his conclusions from the simulations without reinfection. In the first model experiment, I assume that $\tilde{R}$ is fixed over time. This reflects the scenarios when mitigation efforts do not change over time.

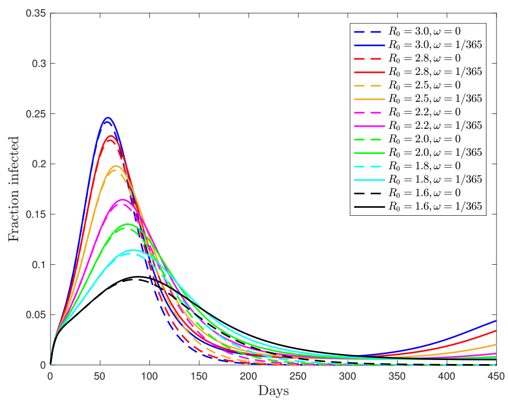
In the first model experiment, I consider a range of values of the basic reproduction number $\tilde{R} = R_0 \in \{1.6, 1.8, 2.0, 2.2, 2.5, 2.8, 3.0\}$. The upper bound of this range captures the estimates from the literature discussed in Section 3.1. Lower values of R_0 correspond to lower levels of the disease transmission. The mitigation measures — quarantine, travel restrictions, or social distancing — can reduce the basic reproduction number. Anderson et al. (2020) provide a thorough discussion of this question. Critically, in my simulations, I vary both ω and R_0. By comparing the simulated series under different values of ω and R_0, I follow two goals. First, given R_0, I compare the outcomes of the reinfection and no-reinfection scenarios. Second, given ω, I demonstrate the effects of the mitigation measures (expressed through the lower values of R_0) under the reinfection and no-reinfection scenarios.

Figure 3.1 shows the time paths for the simulated fraction of the actively infected population with (solid lines) and without (dashed lines) reinfection under different values of R_0. This model experiment implies that lower R_0 leads to delaying the infection peak both with and without reinfection. Second, under the reinfection scenario, the size of the peak is greater than without reinfection. The difference in the peak values is decreasing in R_0. Third, with reinfection, the fraction of the actively infected population exhibits asymmetric dynamics around the peak. Crucially, before the peak, the time paths with and without reinfection are indistinguishable. However, after the peak, the reinfection series is unambiguously above the no-reinfection series. Therefore, by reducing the transmission rate with the mitigation measures, we delay the infection peak, and hence delay the moment when the difference between the reinfection and no-reinfection scenarios becomes sizeable. Finally, notice that, with reinfection, there can be multiple-wave disease outbreaks.

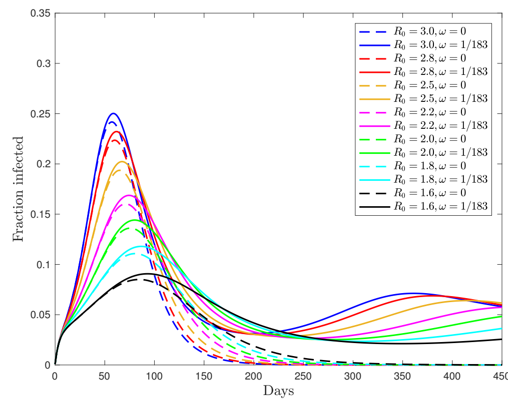
In a related study, Camacho and Cazelles (2013) discuss the role of homologous reinfection in driving multiple-wave influenza outbreaks.

In the second model experiment, I assume that $\tilde{R}$ gradually decreases at different speed. To capture the scenarious under different speed of implementation, following Atkeson (2020), I set $\tilde{R}_1(0) = \tilde{R}_2(0) = 3$, $R_1^* = R_2^* = 1.6$, and vary parameters η_1 and η_2 with $\eta_1 = \eta_2 \equiv \eta$. There are five scenarios: very fast ($\eta = 1/5$), fast ($\eta = 1/10$), moderate ($\eta = 1/20$), slow ($\eta = 1/50$), and very slow ($\eta = 1/100$). Higher values of η govern higher rate of convergence of $\tilde{R}$ to the long-run value of 1.6. Figure 3.2 shows the time paths for $\tilde{R}$ and the simulated fraction of the actively infected population with (solid lines) and without (dashed lines) reinfection. This model experiment implies that the speed of implementation affects the timing of the peak and its size. Faster implementation of mitigation measures leads to delaying the infection peak both with and without reinfection. Next, similarly to the simulation from Figure 3.1, under the reinfection scenario, the fraction of the actively infected population exhibits asymmetric dynamics around the peak. Relative to the no-reinfection scenario, reinfection affects the epidemic duration, the size of the infection peak, and the timing of the infection peak. Furthermore, to provide additional evidence to the dynamics of the solution, in Figure 3.2b I show the phase diagram where plot the fraction of the susceptible population against the fraction of the actively infected population.

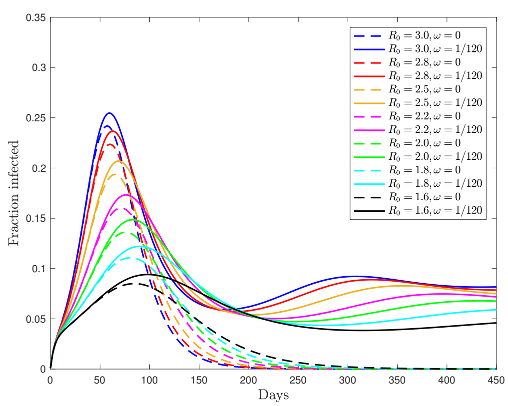
In the third model experiment, I assume that $\tilde{R}$ significantly drops at the beginning, as a result of extremely severe mitigation measures, and then gradually goes up, as the mitigation measures are relaxed. Following Atkeson (2020), I set $\tilde{R}_1(0) = 10$, $\tilde{R}_2(0) = -4$, $R_1^* = -10$, $R_2^* = 4$, $\eta_1 = 1/35$, and $\eta_2 = 1/100$. Given the initial and long-run values of the reproduction number and $\eta_1 > \eta_2$, $\tilde{R}_1(t)$ is rapidly decreasing function while $\tilde{R}_2(t)$ is slowly increasing function. As a result, the time path for $\tilde{R}(t)$ has a U-shaped form, see Figure 3.3a. The other two panels of Figure 3.3 show the simulated fraction of the actively infected population with and without reinfection. Under the temporary and extremely severe mitigation measures, in the first four months, as shown in Figure 3.3b, the fraction of the actively infected population substantially goes down. Moreover, the dynamics is identical for the scenarios with and without the possibility of reinfection. Turning to the first 15 months of the pandemic, shown in Figure 3.3c, we see that gradual relaxation that follows the initial extremely severe mitigation measures, leads to a subsequent peak. Therefore, relaxation of the mitigation measures, driven by the optimistic dynamics in the first months, eventually leads to the epidemic. Motivated by the observation that early mitigation measures delay the peak but not its size, because the population does not acquire herd immunity, Toda (2020) studies the optimal mitigation policy. He shows that it is optimal to initiate the mitigation measures once the number of cases reaches some threshold fraction of the population.



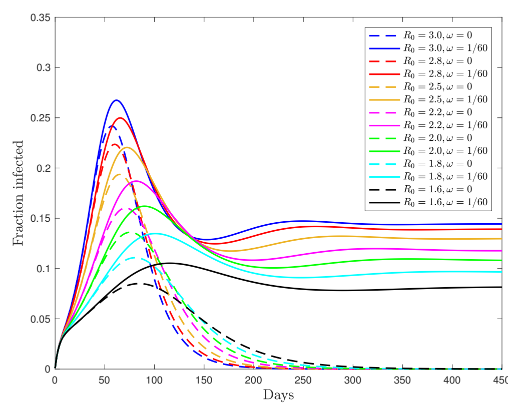
(a) Immunity waning rate $\omega = 1/365$.



(b) Immunity waning rate $\omega = 1/183$.



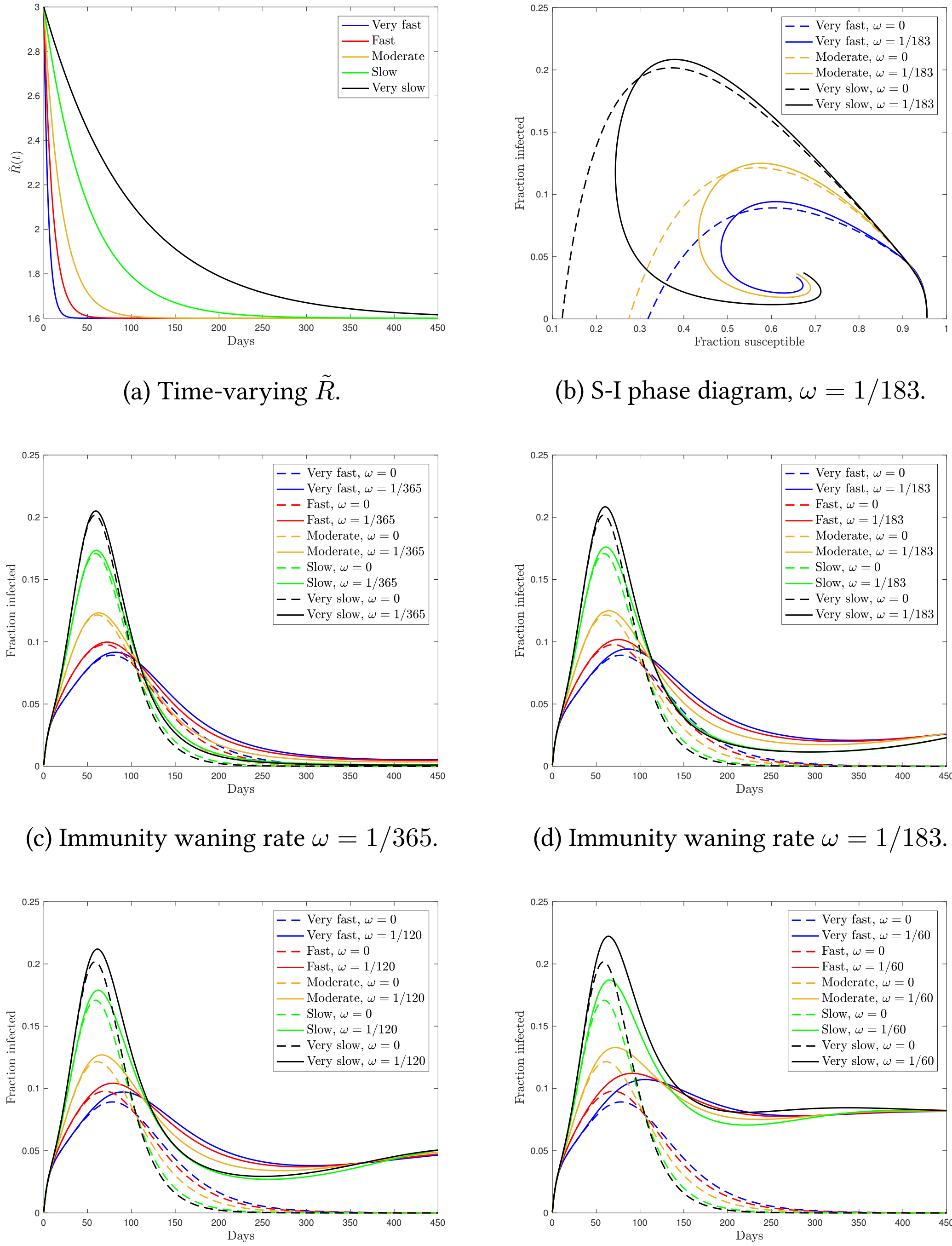
(c) Immunity waning rate $\omega = 1/120$.



(d) Immunity waning rate $\omega = 1/60$.

Figure 3.1: Fraction of Actively Infected Population over Time

Notes: Panels (a)-(d) show the fraction of the actively infected population over time under the reinfection (solid) and no-reinfection (dashed) scenarios and with different values of the basic reproduction number, R_0. Panels (a)-(d) differ in the size of the immunity waning ratio, ω.



(a) Time-varying $\tilde{R}$.

(b) S-I phase diagram, $\omega = 1/183$.

(c) Immunity waning rate $\omega = 1/365$.

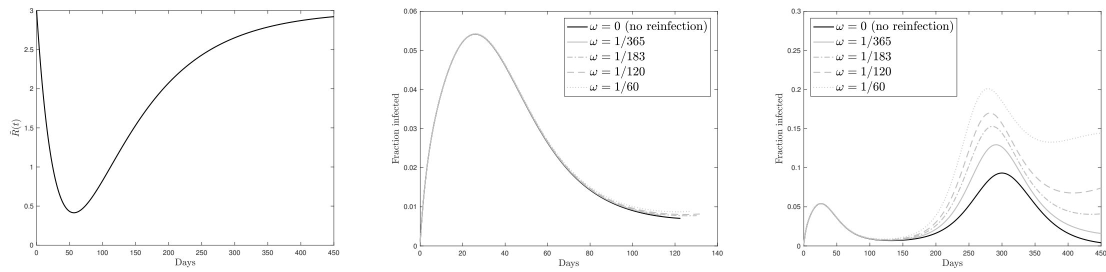
(d) Immunity waning rate $\omega = 1/183$.

(e) Immunity waning rate $\omega = 1/120$.

(f) Immunity waning rate $\omega = 1/60$.

Figure 3.2: Actively Infected Population with Time-Varying Reproduction Number

NOTES: Panel (a) shows the time paths for the time-varying reproduction number, $\tilde{R}$. Panel (b) contains the phase diagram that shows the evolution of the fraction of the actively infected population against the fraction of the susceptible population with and without reinfection. Panels (c)-(e) show the fraction of the actively infected population over time under the reinfection (solid) and no-reinfection (dashed) scenarios and with different speed of the change in $\tilde{R}$.



(a) Time-varying $\tilde{R}$. (b) Infected, first 4 months. (c) Infected, first 15 months.

Figure 3.3: Actively Infected Population with Time-Varying Reproduction Number

NOTES: Panel (a) shows the time path for the time-varying reproduction number, $\tilde{R}$. Panel (b) shows the fraction of the actively infected population over time under the temporary and extremely severe mitigation measures in the first 4 months. Panel (c) shows the fraction of the actively infected population over time under the temporary and extremely severe mitigation measures in the first 15 months. In panels (b) and (c), black solid line ($\omega = 0$) corresponds to the no-reinfection scenario. The grey lines ($\omega > 0$) correspond to the reinfection scenarios. The lines coincide in panel (b).

3.4 Alternative Reinfection Assumptions

3.4.1 Milder Disease after Reinfection

I consider two alternative ways of modeling reinfection. First, I assume that individuals, once being reinfected, have a milder form of the disease. This is in line with An et al. (2020) who discuss the clinical characteristics of the recovered COVID-19 patients with redetectable positive RNA test. When readmitted to the hospital, these patients showed no obvious clinical symptoms or disease progression. In the model, I assume that the individuals who become susceptible after being recovered, have lower transmission rate and higher recovery rate. At each point in time, the population, normalized to one, consists of seven classes: primary-susceptible (S_p), secondary-susceptible (S_s), primary-exposed (E_p), secondary-exposed (E_s), primary-infected (I_p), secondary-infected (I_s), and resistant (recovered) (R):

$$S_p(t) + S_s(t) + E_p(t) + E_s(t) + I_p(t) + I_s(t) + R(t) = N, \quad \forall t \geq 0 \tag{3.13}$$

Individuals belong to S_p, E_p, or I_p if they were not infected before. Individuals belong to S_s, E_s, or I_s after being recovered. The compartmental model is formulated as follows:

$$\frac{dS_p(t)}{dt} = -\left(\beta_p I_p(t) + \beta_s I_s(t)\right) \frac{S_p(t)}{N} \tag{3.14}$$

$$\frac{dS_s(t)}{dt} = -\left(\beta_p I_p(t) + \beta_s I_s(t)\right) \frac{S_s(t)}{N} + \omega R(t) \tag{3.15}$$

$$\frac{dE_p(t)}{dt} = \left(\beta_p I_p(t) + \beta_s I_s(t)\right) \frac{S_p(t)}{N} - \sigma_p E_p(t) \tag{3.16}$$

$$\frac{dE_s(t)}{dt} = \left(\beta_p I_p(t) + \beta_s I_s(t)\right) \frac{S_s(t)}{N} - \sigma_s E_s(t) \tag{3.17}$$

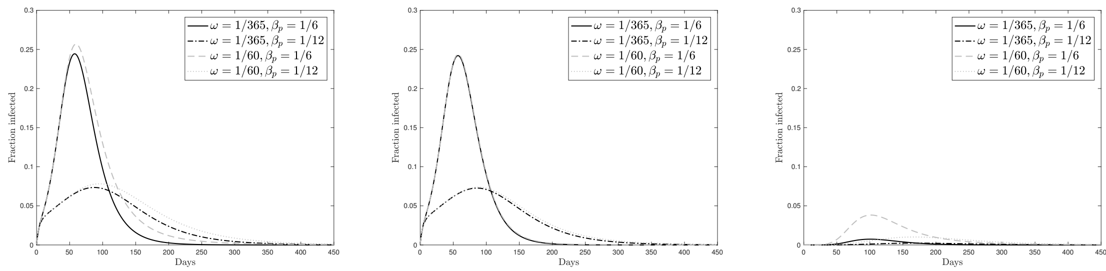
$$\frac{dI_p(t)}{dt} = \sigma_p E_p(t) - \gamma_p I_p(t) \tag{3.18}$$

$$\frac{dI_s(t)}{dt} = \sigma_s E_s(t) - \gamma_s I_s(t) \tag{3.19}$$

$$\frac{dR(t)}{dt} = \gamma_p I_p(t) + \gamma_s I_s(t) - \omega R(t) \tag{3.20}$$

Note that susceptible individuals, both those who have never been infected and those who have recovered and are currently susceptible again, become exposed after contacting with both primary- and secondary-infected individuals. In the absence of the parameter estimates for COVID-19, I assume that $\beta_s = \beta_p/2$, $\gamma_s = 2\gamma_p$, and $\sigma_s = \sigma_p$. Following the previous simulations, I set $\sigma_p = 1/5.2$ and $\gamma_p = 1/18$. The initial values are $I_p(0) = 1/1000$, $E_p(0) = 43.75 \times I_p(0)$, as in Section 3.2, and $S_s(0) = E_s(0) = I_s(0) = R(0) = 0$.

Figure 3.4 shows the simulated time paths for the fraction of the actively infected population — total (primary and secondary), primary, and secondary. In these simulations, I consider several scenarios. They are characterized by four combinations of the immunity waning rate and primary-transmission rate, β_p. The immunity waning rate takes two values, $\omega = 1/365$ and $\omega = 1/60$. Thus, I use the lower and upper bounds of the range considered in the previous simulations. The primary-transmission rate also takes two values, $\beta_p = 1/6$ and $\beta_p = 1/12$. The case $\beta_p = 1/6$ corresponds to $R_0 = 3.0$ in the baseline SEIRS model from Section 3.2, while the case $\beta_p = 1/12$ corresponds to $R_0 = 1.5$. We can see from Figure 3.4 that the dynamics of the total fraction of the actively infected population is almost entirely driven by the primary-infected people. There is a limited role of reinfection in the general epidemic dynamics.



(a) Infected (total). (b) Primary-infected. (c) Secondary-infected.

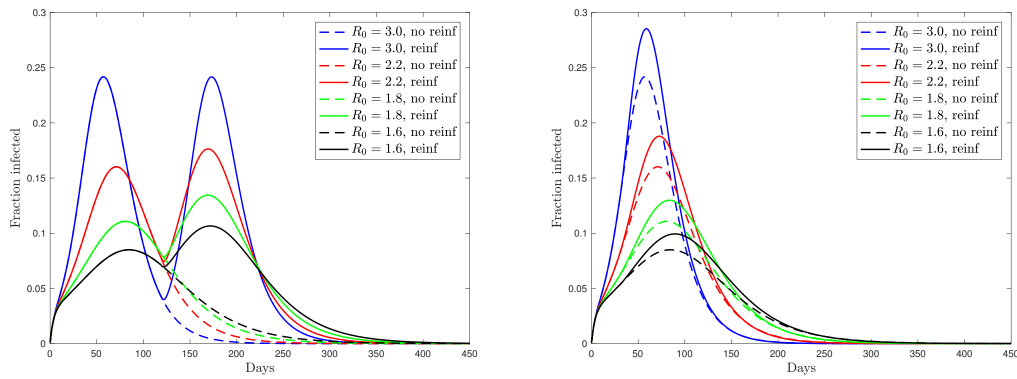
Figure 3.4: Actively Infected Population over Time, Milder Disease after Reinfection

NOTES: Panel (a) shows the fraction of the total (primary and secondary) actively infected population over time. Panel (b) shows the fraction of the actively primary-infected population over time. Panel (c) shows the fraction of the actively secondary-infected population over time. Panels (a)-(c) consider various combinations of the immunity waning rate, ω, and the primary-transmission rate, β_p.

3.4.2 One-Time Reinfection

Second, instead of a constant immunity waning rate, I assume that the individuals, that are resistant at date t^* (those who were infected in the past), become susceptible again. In particular, I consider a standard SEIR model, i.e. one described by equations (3.1)-(3.5) with $\omega = 0$. Before date t^*, the dynamics of the model coincides with the no-reinfection case. At date t^*, resistant individuals join the pool of susceptible population. Formally this is described by $S(t^*) = S(t^* - dt) + R(t^* - dt)$ as $dt \to 0$. Therefore, at date t^* the fraction of resistant population goes down to zero, while the fraction of susceptible population discretely goes up. To illustrate the patterns that arise under this modeling approach of reinfection, I choose two time thresholds, $t^* = 120$ and $t^* = 30$.

Figure 3.5 shows the time paths for the fraction of the actively infected population. For each scenario, I consider a range of the basic reproduction number values. First, my model simulations imply that if the infection peak occurs before t^*, as in Figure 3.5a, then reinfection leads to a double peak. Second, if the infection peak occurs shortly after t^*, as in Figure 3.5b, then reinfection results in a higher single peak. Notice that the simulated series are consistent with the conclusion from Section 3.3 that the mitigation measures (lower R_0) delay not only the infection peak, but also the moment when the difference between the reinfection and no-reinfection scenarios becomes prominent.



(a) Reinfection time $t^* = 120$.

(b) Reinfection time $t^* = 30$.

Figure 3.5: Actively Infected Population over Time, One-Time Reinfection

NOTES: Fraction of the actively infected population over time under the reinfection (solid) and no-reinfection (dashed) scenarios and with different values of the basic reproduction number, R_0. Panels (a)-(b) differ in the time of reinfection.

3.5 Conclusion

To date, the immune response, including duration of immunity, to SARS-CoV-2 infection is not yet understood. Unless it is clearly known that patients with COVID-19 are unlikely to be reinfected, it is instructive to consider the possible scenarios. In this paper, I study how the possibility of reinfection shapes the epidemiological dynamics at the population level. To explore the difference in the dynamics of the disease under the reinfection and no-reinfection scenarios and, furthermore, the effects of the mitigation measures, I use a SEIRS model and consider three different ways of modeling reinfection. A key finding is that the mitigation measures delay not only the infection peak, but also the moment when the difference between the reinfection and no-reinfection scenarios becomes prominent. This result is robust to various modeling assumptions. The framework is simple and therefore can serve as a baseline for more complex models.

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Appendix A

Appendix to Chapter 1

A.1 Proofs

A.1.1 Proof of Proposition 1.1

I prove a more general version of Proposition 1.1. In particular, I also consider the case when married couples file separately, and hence spouses are taxed on their individual income.

Single Households. Suppose $q = 0$ and $\tilde{T} = 0$. Consider the problem of a single individual given in (1.2). Denoting by μ the Lagrange multiplier corresponding to the budget constraint, I obtain the following first-order conditions:

$$\frac{1}{c} = \mu \qquad [c]$$

$$\psi n_i^{\eta} = \mu \lambda_s \left(1 - \tau_s\right) w_i^{1-\tau_s} n_i^{-\tau_s} \qquad [n]$$

Plugging the budget constraint into the FOC for consumption and then plugging the resulting expression into the FOC for working hours, I get

$$n = \left(\frac{1 - \tau_s}{\psi}\right)^{\frac{1}{1+\eta}} \tag{A.1}$$

Next, the optimal labor income and consumption are given by

$$y = \left(\frac{1 - \tau_s}{\psi}\right)^{\frac{1}{1+\eta}} w_i \tag{A.2}$$

$$c = \lambda_s \left(\frac{1 - \tau_s}{\psi}\right)^{\frac{1-\tau_s}{1+\eta}} \left(w_i\right)^{1-\tau_s} \tag{A.3}$$

Taking logarithms, I obtain the elasticities of consumption, working hours, and labor income to wage shock (transmission coefficients):

$$\frac{d \log(c)}{d \log\left(w_i\right)} = 1 - \tau_s \tag{A.4}$$

$$\frac{d \log(n)}{d \log\left(w_i\right)} = 0 \tag{A.5}$$

$$\frac{d\log(y)}{d\log(w_i)} = 1 \tag{A.6}$$

This completes the proof of Proposition 1.1 for singles.

Married Couples (Joint Taxation). Suppose $q = 0$ and $\tilde{T} = 0$. Consider the problem of a married couple given in (1.3). Denoting by μ the Lagrange multiplier corresponding to the budget constraint, I obtain the following first-order conditions:

$$\frac{2}{c} = \mu \qquad [c]$$

$$\psi n_m^\eta = \mu\lambda_j (1-\tau_j) w_m (w_m n_m + w_f n_f)^{-\tau_j} \qquad [n_m]$$

$$\psi n_f^\eta = \mu\lambda_j (1-\tau_j) w_f (w_m n_m + w_f n_f)^{-\tau_j} \qquad [n_f]$$

Plugging the budget constraint into the FOC for consumption and then plugging the resulting expression into the FOCs for working hours, I get

$$\psi n_m^\eta = 2(1-\tau_j) w_m (w_m n_m + w_f n_f)^{-1}$$

$$\psi n_f^\eta = 2(1-\tau_j) w_f (w_m n_m + w_f n_f)^{-1}$$

Note that it follows from the FOCs for working hours that

$$\frac{n_m}{n_f} = \left(\frac{w_m}{w_f}\right)^{\frac{1}{\eta}}$$

Plugging this relation into the equations above, I obtain

$$\psi n_m^{1+\eta} = 2(1-\tau_j)\left[1 + \left(\frac{w_f}{w_m}\right)^{\frac{1+\eta}{\eta}}\right]^{-1}$$

$$\psi n_f^{1+\eta} = 2(1-\tau_j)\left[1 + \left(\frac{w_m}{w_f}\right)^{\frac{1+\eta}{\eta}}\right]^{-1}$$

Finally, the optimal working hours, labor income, and consumption are given by

$$n_i = \left(\frac{2(1-\tau_j)}{\psi}\right)^{\frac{1}{1+\eta}} \left[1 + \left(\frac{w_{-i}}{w_i}\right)^{\frac{1+\eta}{\eta}}\right]^{-\frac{1}{1+\eta}} \tag{A.7}$$

$$y_i = \left(\frac{2(1-\tau_j)}{\psi}\right)^{\frac{1}{1+\eta}} \left[1 + \left(\frac{w_{-i}}{w_i}\right)^{\frac{1+\eta}{\eta}}\right]^{-\frac{1}{1+\eta}} w_i \tag{A.8}$$

$$c = \lambda_j \left(\frac{2(1-\tau_j)}{\psi}\right)^{\frac{1-\tau_j}{1+\eta}} \left[(w_m)^{\frac{1+\eta}{\eta}} + (w_f)^{\frac{1+\eta}{\eta}}\right]^{\frac{\eta(1-\tau_j)}{1+\eta}} \tag{A.9}$$

where I denote the gender of a spouse by $-i$.

Taking logarithms, I obtain the elasticities of consumption, individual i's labor income, and his/her spouse's labor income to individual i's wage shock (transmission coefficients):

$$\frac{d\log(c)}{d\log(w_i)} = \frac{(w_i)^{\frac{1+\eta}{\eta}}}{(w_i)^{\frac{1+\eta}{\eta}} + (w_{-i})^{\frac{1+\eta}{\eta}}} (1-\tau_j) < 1 - \tau_j \tag{A.10}$$

$$\frac{d\log(y_i)}{d\log(w_i)} = \underbrace{1}_{\text{direct wage effect}} + \underbrace{\frac{1}{\eta} \cdot \frac{(w_{-i})^{\frac{1+\eta}{\eta}}}{(w_i)^{\frac{1+\eta}{\eta}} + (w_{-i})^{\frac{1+\eta}{\eta}}}}_{\text{labor supply effect}} > 1 \tag{A.11}$$

$$\frac{d\log(y_{-i})}{d\log(w_i)} = -\frac{1}{\eta} \cdot \frac{(w_i)^{\frac{1+\eta}{\eta}}}{(w_i)^{\frac{1+\eta}{\eta}} + (w_{-i})^{\frac{1+\eta}{\eta}}} < 0 \tag{A.12}$$

This completes the proof of Proposition 1.1 for married couples under joint taxation.

Married Couples (Separate Taxation). Consider the problem of a married couple given by

$$\max_{c,n_m,n_f} 2\log(c) - \psi\frac{n_m^{1+\eta}}{1+\eta} - \psi\frac{n_f^{1+\eta}}{1+\eta} \tag{A.13}$$

$$\text{s.t.} \quad c = \lambda_{sep}(w_m n_m)^{1-\tau_{sep}} + \lambda_{sep}(w_f n_f)^{1-\tau_{sep}}$$

Denoting by μ the Lagrange multiplier corresponding to the budget constraint, I obtain the following first-order conditions:

$$\frac{2}{c} = \mu \tag{$[c]$}$$

$$\psi n_m^{\eta} = \mu \lambda_{sep} \left(1 - \tau_{sep}\right) w_m^{1-\tau_{sep}} n_m^{-\tau_{sep}} \qquad [n_m]$$

$$\psi n_f^{\eta} = \mu \lambda_{sep} \left(1 - \tau_{sep}\right) w_f^{1-\tau_{sep}} n_f^{-\tau_{sep}} \qquad [n_f]$$

Plugging the budget constraint into the FOC for consumption and then plugging the resulting expression into the FOCs for working hours, I get

$$\psi n_m^{\eta+\tau_{sep}} = 2\left(1 - \tau_{sep}\right) w_m^{1-\tau_{sep}} \left[\left(w_m n_m\right)^{1-\tau_{sep}} + \left(w_f n_f\right)^{1-\tau_{sep}}\right]^{-1}$$

$$\psi n_f^{\eta+\tau_{sep}} = 2\left(1 - \tau_{sep}\right) w_f^{1-\tau_{sep}} \left[\left(w_m n_m\right)^{1-\tau_{sep}} + \left(w_f n_f\right)^{1-\tau_{sep}}\right]^{-1}$$

Note that it follows from the FOCs for working hours that

$$\frac{n_m}{n_f} = \left(\frac{w_m}{w_f}\right)^{\frac{1-\tau_{sep}}{\eta+\tau_{sep}}}$$

Plugging this relation into the equations above, I obtain

$$\psi n_m^{1+\eta} = 2\left(1 - \tau_{sep}\right) \left[1 + \left(\frac{w_f}{w_m}\right)^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}\right]^{-1}$$

$$\psi n_f^{1+\eta} = 2\left(1 - \tau_{sep}\right) \left[1 + \left(\frac{w_m}{w_f}\right)^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}\right]^{-1}$$

Finally, the optimal working hours, labor income, and consumption are given by

$$n_i = \left(\frac{2(1 - \tau_{sep})}{\psi}\right)^{\frac{1}{1+\eta}} \left[1 + \left(\frac{w_{-i}}{w_i}\right)^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}\right]^{-\frac{1}{1+\eta}} \tag{A.14}$$

$$y_i = \left(\frac{2(1 - \tau_{sep})}{\psi}\right)^{\frac{1}{1+\eta}} \left[1 + \left(\frac{w_{-i}}{w_i}\right)^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}\right]^{-\frac{1}{1+\eta}} w_i \tag{A.15}$$

$$c = \lambda_{sep} \left(\frac{2(1 - \tau_{sep})}{\psi}\right)^{\frac{1-\tau_{sep}}{1+\eta}} \left[w_m^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_s+\eta}} + w_f^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}\right]^{\frac{\tau_{sep}+\eta}{1+\eta}} \tag{A.16}$$

where I denote the gender of a spouse by $-i$.

Taking logarithms, I obtain the elasticities of consumption, individual i's labor income, and his/her spouse's labor income to individual i's wage shock (transmission coefficients):

$$\frac{d\log(c)}{d\log(w_i)} = \frac{w_i^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}}{w_i^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}} + w_{-i}^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}} (1-\tau_{sep}) < 1 - \tau_{sep} \tag{A.17}$$

$$\frac{d\log(y_i)}{d\log(w_i)} = \underbrace{1}_{\text{direct wage effect}} + \underbrace{\frac{1-\tau_{sep}}{\tau_{sep}+\eta} \cdot \frac{w_{-i}^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}}{w_i^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}} + w_{-i}^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}}}_{\text{labor supply effect}} > 1 \tag{A.18}$$

$$\frac{d\log(y_{-i})}{d\log(w_i)} = -\frac{1-\tau_{sep}}{\tau_{sep}+\eta} \cdot \frac{w_i^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}}{w_i^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}} + w_{-i}^{\frac{(1+\eta)(1-\tau_{sep})}{\tau_{sep}+\eta}}} < 0 \tag{A.19}$$

This completes the proof of Proposition 1.1. ■

A.1.2 Proof of Proposition 1.2

First, consider the case when a single individual works. Solving problem (1.2) along the lines of the proof of Proposition 1.1, I obtain the indirect utility:

$$V_1^s\left(c_1^*, n^*; q\right) = \log\left(\lambda_s \left(wn^*\right)^{1-\tau_s} + \tilde{T}\right) - \psi \frac{\left(n^* + q\right)^{1+\eta}}{1+\eta} \tag{A.20}$$

where c_1^* and n^* denote the optimal choices.

Next, in the case when a single individual does not work, the indirect utility is given by

$$V_0^s\left(c_0^*, 0\right) = \log\left(\tilde{T}\right) \tag{A.21}$$

Define a threshold on the fixed cost of work $\bar{q}_s$ through the following equation:

$$V_1^s\left(c_1^*, n^*; \bar{q}_s\right) = V_0^s\left(c_0^*, 0\right) \tag{A.22}$$

Using (A.20) and (A.21), I obtain

$$\log\left(\lambda_s\left(wn^*\right)^{1-\tau_s}+\tilde{T}\right)-\psi\frac{\left(n^*+\bar{q}_s\right)^{1+\eta}}{1+\eta}=\log\left(\tilde{T}\right) \tag{A.23}$$

Equation (A.23) implicitly defines $\bar{q}_s$ as a function of τ_s. Using the envelope theorem, it follows that

$$\frac{\partial V_1^s\left(c_1^*,n^*;\bar{q}_s\right)}{\partial\tau_s}+\frac{\partial V_1^s\left(c_1^*,n^*;\bar{q}_s\right)}{\partial q}\cdot\frac{\partial\bar{q}_s}{\partial\tau_s}=\frac{\partial V_0^s\left(c_0^*,0\right)}{\partial\tau_s}=0 \tag{A.24}$$

I have

$$\frac{\partial V_1^s\left(c_1^*,n^*;\bar{q}_s\right)}{\partial q}<0 \tag{A.25}$$

Furthermore,

$$\frac{\partial V_1^s\left(c_1^*,n^*;\bar{q}_s\right)}{\partial\tau_s}>0 \tag{A.26}$$

because $wn^*<1$, i.e. the individual earns less than the average income.

Combining (A.26) and (A.25) and plugging them into (A.24), I obtain

$$\frac{\partial\bar{q}_s}{\partial\tau_s}=-\frac{\partial V_1^s\left(c_1^*,n^*;\bar{q}_s\right)/\partial\tau_s}{\partial V_1^s\left(c_1^*,n^*;\bar{q}_s\right)/\partial q}>0 \tag{A.27}$$

This completes the proof of Proposition 1.2. ■

A.1.3 Proof of Proposition 1.3

First, consider the case when both spouses work. Solving problem (1.3) along the lines of the proof of Proposition 1.1, I obtain the indirect utility:

$$V_2^c\left(c_2^*,n_{m,2}^*,n_f^*;q\right)=2\log\left(\lambda_j\left(w_m n_{m,2}^*+w_f n_f^*\right)^{1-\tau_j}\right)-\psi\frac{\left(n_{m,2}^*\right)^{1+\eta}}{1+\eta}-\psi\frac{\left(n_f^*+q\right)^{1+\eta}}{1+\eta} \tag{A.28}$$

where c_2^*, $n_{m,2}^*$, and n_f^* denote the optimal choices.

Next, in the case of a single-earner couple, the indirect utility is given by

$$V_1^c\left(c_1^*, n_{m,1}^*, 0\right) = 2\log\left(\lambda_j\left(w_m n_{m,1}^*\right)^{1-\tau_j}\right) - \psi\frac{\left(n_{m,1}^*\right)^{1+\eta}}{1+\eta} =$$
$$2\left[\log(\lambda_j) + \frac{1-\tau_j}{1+\eta}\log\left(\frac{2\left(1-\tau_j\right)}{\psi}\right) + \left(1-\tau_j\right)\log\left(w_m\right)\right] - \frac{1-\tau_j}{1+\eta} \quad \text{(A.29)}$$

where c_1^* and $n_{m,1}^*$ denote the optimal choices.

Define a threshold on the fixed cost of work $\bar{q}_c$ through the following equation:

$$V_2^c\left(c_2^*, n_{m,2}^*, n_f^*; \bar{q}_c\right) = V_1^c\left(c_1^*, n_{m,1}^*, 0\right) \quad \text{(A.30)}$$

Using (A.28) and (A.29), I obtain

$$2\log\left(\lambda_j\left(w_m n_{m,2}^* + w_f n_f^*\right)^{1-\tau_j}\right) - \psi\frac{\left(n_{m,2}^*\right)^{1+\eta}}{1+\eta} - \psi\frac{\left(n_f^* + \bar{q}_c\right)^{1+\eta}}{1+\eta} =$$
$$2\log\left(\lambda_j\left(w_m n_{m,1}^*\right)^{1-\tau_j}\right) - \psi\frac{\left(n_{m,1}^*\right)^{1+\eta}}{1+\eta} \quad \text{(A.31)}$$

Equation (A.31) implicitly defines $\bar{q}_c$ as a function of τ_j. Using the envelope theorem, it follows that

$$\frac{\partial V_2^c\left(c_2^*, n_{m,2}^*, n_f^*; \bar{q}_c\right)}{\partial \tau_j} + \frac{\partial V_2^c\left(c_2^*, n_{m,2}^*, n_f^*; \bar{q}_c\right)}{\partial q} \cdot \frac{\partial \bar{q}_c}{\partial \tau_j} = \frac{\partial V_1^c\left(c_1^*, n_{m,1}^*, 0\right)}{\partial \tau_j} \quad \text{(A.32)}$$

I have

$$\frac{\partial V_2^c\left(c_2^*, n_{m,2}^*, n_f^*; \bar{q}_c\right)}{\partial q} < 0 \quad \text{(A.33)}$$

Furthermore,

$$\frac{\partial V_1^c\left(c_1^*, n_{m,1}^*, 0\right)}{\partial \tau_j} - \frac{\partial V_2^c\left(c_2^*, n_{m,2}^*, n_f^*; \bar{q}_c\right)}{\partial \tau_j} < 0 \quad \text{(A.34)}$$

because consumption of a dual-earner couple is higher than consumption of a single-earner couple.

Combining (A.34) and (A.33) and plugging them into (A.32), I obtain

$$\frac{\partial \bar{q}_c}{\partial \tau_j} = -\frac{\partial V_1^c\left(c_1^*, n_{m,1}^*, 0\right)/\partial \tau_j - \partial V_2^c\left(c_2^*, n_{m,2}^*, n_f^*; \bar{q}_c\right)/\partial \tau_j}{\partial V_2^c\left(c_2^*, n_{m,2}^*, n_f^*; \bar{q}_c\right)/\partial q} < 0 \tag{A.35}$$

This completes the proof of Proposition 1.3. ■

A.2 Tax and Transfer Function

A.2.1 Properties of Tax and Transfer Function

As discussed in the main text, I use the tax and transfer function given by

$$T(y) = y - \lambda y^{1-\tau} \tag{A.36}$$

This function is characterized by two parameters. Parameter λ governs the average level of taxes. Parameter τ, which is the focus of this paper, stands for the degree of tax progressivity. It is tightly related to the coefficient of residual income progression (Musgrave, 1959; Jakobsson, 1976). In particular,

$$1 - \underbrace{\frac{1 - MTR}{1 - ATR}}_{\text{residual income progression}} = 1 - \frac{\lambda(1-\tau)y^{-\tau}}{\lambda y^{-\tau}} = \tau \tag{A.37}$$

where MTR is the marginal tax rate and ATR is the average tax rate. Furthermore, from

$$\underbrace{\log\left(y - T(y)\right)}_{\text{log post-tax/transfer income}} = \log(\lambda) + (1-\tau) \times \underbrace{\log(y)}_{\text{log pre-tax/transfer income}} \tag{A.38}$$

it follows that the average elasticity of post-tax/transfer income to pre-tax/transfer income is equal to $1 - \tau$.

In the case of $\tau \in (0, 1]$, the tax and transfer system is progressive. In the context of (A.37), it means that marginal tax rates always exceed average tax rates. Furthermore, through the lens of equation (A.38), it means that the more progressive tax system, i.e. with higher τ, reduces the elasticity of post-tax/transfer to pre-tax/transfer income. In turn, when $\tau < 0$, the tax and transfer system is regressive. Finally, in the case of $\tau = 0$, the tax and transfer system is flat, and the marginal and average tax rates are equal to $1-\lambda$. Note that specification (A.36) allows for transfers. In particular, if the gross household income y is below the break-even level $\lambda^{\frac{1}{\tau}}$, then $T(y) < 0$.

In Appendix A.2.2, I discuss the details of the estimation of parameters τ and λ.

A.2.2 Estimation of Tax and Transfer Function Parameters

Taking logarithms on both sides of $y - T(y) = \lambda y^{1-\tau}$, I obtain

$$\log\left(y - T(y)\right) = \log(\lambda) + (1-\tau)\log(y) \tag{A.39}$$

Using (A.39), I estimate parameters λ and τ by regressing the logarithm of post-tax/transfer household income on the logarithm of the pre-tax/transfer taxable household income separately for single individuals and married couples. Importantly, I express y in terms of the average wage earnings.

I use the data from the PSID for survey years 2013, 2015, and 2017. For each household in the sample, I construct the measures of pre-tax/transfer and post-tax/transfer income. Having done that, I use the NBER TAXSIM (Feenberg and Coutts, 1993) to calculate the corresponding tax liabilities. To prepare the inputs for the NBER TAXSIM, I follow Kimberlin et al. (2015) and Heathcote et al. (2017). The pre-tax/transfer gross household income is defined as the sum of all income received in a given tax year, including labor income, self-employment income, property income, interest income, dividends, retirement income, and private transfers. The pre-tax/transfer taxable household income is defined as the pre-tax/transfer gross household income minus deductible expenses (medical expenses, mortgage interest, state taxes, and charitable contributions)[35] plus the employment share (50%) of the Federal Insurance Contribution Act (FICA) tax. The post-tax/transfer income is defined as the pre-tax/transfer taxable income plus public transfers minus tax liabilities (federal, state, and FICA) calculated by the NBER TAXSIM.

I take the data on medical expenses, mortgage interest, and state taxes directly from

[35] Given the value of deductions, the NBER TAXSIM calculates whether it is better to take the standard deduction or to itemize deductions.

the PSID. Medical expenses are comprised of nursing home and hospital bills, doctor, outpatient surgery, and dental bills, and prescriptions, in-home medical care, special facilities, and other medical services.[36] To calculate the mortgage interest, I use the amount reported in response to the PSID question: *"About how much is the remaining principal on this mortgage?"*[37] I cap this amount at $1 million. To obtain the interest payments, I multiply it by 3.87% which is the average 30-year conventional annual mortgage rate between 2012 and 2016.[38] Because the PSID does not have data on charitable contributions, I impute them. From the SOI data, I calculate that in 2012 charitable contributions constitute about 3% of income for individuals with income above $75000.[39]

As stated above, I add the employment share (50%) of the FICA tax to the measure of pre-tax/transfer taxable income. The FICA tax is comprised of the Old-Age, Survivors, and Disability Insurance (OASDI) tax and the Medicare Hospital Insurance (HI) tax. In 2012-2016, the OASDI tax rate was set at 6.2% for both employees and employers. It was applicable up to an earnings limit which varied from $110100 in 2012 to $118500 in 2016 (in nominal USD).[40] In 2012-2016, the HI tax rate was set at 1.45% for both employees and employers. There was no earnings limit.

In constructing the measure of post-tax/transfer income, I also add the present value imputed gain in social security benefits ($\widetilde{ssb}_{\tilde{a}}^{i}$) that individual i accrues from working at age $\tilde{a}$ to the measure of public transfers. To calculate its value, I follow Heathcote et al. (2017). In particular, for every individual in the sample, I estimate an age-earnings profile $\varphi(a; g, e)$ conditional on gender g and education e using a cubic polynomial in age. I consider four education categories: less than high-school, high-school degree, some

[36] Variables ER57491, ER64613, ER70689 (expenditures on nursing home and hospital bills), ER57497, ER64619, ER70694 (expenditures on doctor, outpatient surgery, and dental bills), ER57503, ER64625, ER70698 (expenditures on prescriptions, in-home medical care, special facilities, and other services).

[37] Variables ER53048, ER60049, and ER66051.

[38] Source: https://fred.stlouisfed.org/series/MORTG

[39] Table 2.1 "Returns with Itemized Deductions: Sources of Income, Adjustments, Itemized Deductions by Type, Exemptions, and Tax Items." The resulting fraction, 3%, is consistent with the evidence from List (2011) and Heathcote et al. (2017).

[40] Source: https://www.ssa.gov/oact/COLA/cbb.html#Series

college, and college degree and above. Estimated earnings at age a^* are then given by

$$\hat{y}^i_{a^*} = \frac{\varphi(a^*; g, e)}{\varphi(a; g, e)} y^i_a$$

Denote the Average Index of Monthly Earnings (AIME) by $AIME_i$. When individual i works from age $a = 1$ to retirement age $a_R = 41$ (from age 25 to age 65 in the data), it is given by

$$AIME_i = \frac{1}{12} \cdot \left(\frac{\sum_{a=1}^{a_R} \hat{y}^i_a}{a_R} \right)$$

Next, I define the counterfactual AIME calculated under the assumption that an individual does not work at age $\tilde{a}$:

$$AIME^{\tilde{a}}_i = AIME_i - \frac{1}{12} \cdot \frac{y^i_{\tilde{a}}}{a_R}$$

The associated annualized gain in social security benefits from working at age $\tilde{a}$ is given by

$$ssb^i_{\tilde{a}} = \left[PIA(AIME_i) - PIA\left(AIME^{\tilde{a}}_i\right) \right] \cdot 12$$

where PIA is the "Primary Insurance Amount" (PIA) formula that determines monthly benefits as a function of AIME.[41]

Assuming the annual interest rate $R = 1.04$ and the maximum possible age $A = 76$ (age 100 in the data), I calculate the present value of individual i's pension gain from working at age $\tilde{a}$:

$$\widetilde{ssb}^i_{\tilde{a}} = \left(\frac{1}{a_R} \right)^{a_R - \tilde{a}} \cdot ssb^i_{\tilde{a}} \cdot \sum_{a=a_R}^{A} \left(\frac{1}{R} \right)^{a - a_R} \zeta_{\tilde{a},a}$$

where $\zeta_{\tilde{a},a}$ is the survival probability from age $\tilde{a}$ to age a (see Table A.1 for ages 65-100). I add $\widetilde{ssb}^i_{\tilde{a}}$ to the measure of post-government income as a part of the public transfers.

[41] See https://www.ssa.gov/oact/COLA/piaformula.html for the details.

A.3 Data and Parameterization

A.3.1 Data

My main data sources include the Panel Study of Income Dynamics (PSID) and the Current Population Survey (CPS). The PSID is the longest-running representative household panel of U.S. individuals and the family units in which they reside. The waves are annual between 1968 and 1997, and biennial starting from 1999. I use the PSID to estimate the parameters of the tax and transfer function and the labor productivity processes for men and women. The sample consists of single and married individuals (heads and wives) who are observed at least twice over the period of 1968-2017. The CPS is the source of official U.S. government statistics on employment, and is designed to be representative of the civilian non-institutional population. I use the CPS to construct the lifecycle profiles of working hours and employment.

In addition, to get the estimates of the age-dependent survival probabilities, I use the data from the National Center for Health Statistics. To estimate the degree of tax progressivity for households with and without children, I use the data from the Congressional Budget Office.

I deflate all nominal variables into 2013 U.S. dollars using the Consumer Price Index for All Urban Consumers (CPI-U). In general, since the CPI suffers from well-documented biases, there are several other price indices that are actively used in the literature. One alternative is the Personal Consumption Expenditures price index (PCE price index). The Bureau of Economic Analysis uses a Fisher index to construct it, and therefore mitigates the small-sample and substitution biases, as well as the weighting bias because it computes weights using business sales data. However, Furth (2017) estimates that a conservative lower bound on the upward bias in the PCE price index is still non-zero and equals to 0.4% p.a.

A.3.2 Method of Simulated Moments

I parameterize my model using a two-stage procedure. In the first stage, I estimate the vector of parameters χ without explicitly using the structural model. For example, as discussed by Gourinchas and Parker (2002), to estimate the variance of permanent and transitory income shocks, one can use time-series moment conditions and true household-level panel data on income, rather than using the data on average consumption and income profiles, where identification might prove difficult in practice. In the second stage, I use the Method of Simulated Moments (MSM) (Pakes and Pollard, 1989; Duffie and Singleton, 1993) to estimate the remaining parameters $\mathbf{\Theta}$:

$$\mathbf{\Theta} = \left(\beta, \psi, \gamma_0^m, \left(\alpha_0^{i,\iota}, \alpha_1^{i,\iota}, \alpha_2^{i,\iota}\right), \bar{L}_\iota^i\right) \tag{A.40}$$

In particular, given the parameters obtained in the first stage, I use the model to simulate the lifecycle profiles of a representative population of people, and then choose the parameter values that minimize the distance between simulated and empirical profiles. To pin down the parameters (A.40), I use the following moments from the U.S. data: the capital-income ratio, the average female-to-male hourly wage ratio, and the lifecycle profiles of employment and hours of work (conditional on employment) for single men and women and married men and women between age 25 and age 65.

Suppose there is data on n individuals, each is observed for up to T years. Denote by $g\left(\mathbf{\Theta}; \boldsymbol{\chi}_0\right)$ the vector of the moment conditions, and by $\hat{g}_n\left(\mathbf{\Theta}; \boldsymbol{\chi}_0\right)$ its sample analog. The MSM estimator minimizes over $\mathbf{\Theta}$ and is given by

$$\hat{\mathbf{\Theta}} = \underset{\mathbf{\Theta}}{\operatorname{argmin}}\, \hat{g}_n\left(\mathbf{\Theta}; \boldsymbol{\chi}_0\right)' \widehat{\boldsymbol{W}}_n \hat{g}_n\left(\mathbf{\Theta}; \boldsymbol{\chi}_0\right) \tag{A.41}$$

where $\widehat{\boldsymbol{W}}_n$ is a $T \times T$ weighting matrix. In the case when $\widehat{\boldsymbol{W}}_n$ is the identity matrix, the estimation procedure is equivalent to minimizing the sum of squared residuals. Following the literature, I treat vector of parameters $\boldsymbol{\chi}_0$ as known.

Under the regularity conditions stated in Pakes and Pollard (1989) and Duffie and Singleton (1993), the MSM estimator $\hat{\mathbf{\Theta}}$ is both consistent and asymptotically normally distributed:

$$\sqrt{n}\left(\widehat{\mathbf{\Theta}} - \mathbf{\Theta}_0\right) \rightsquigarrow \mathcal{N}\left(0, \boldsymbol{V}\right) \tag{A.42}$$

The variance-covariance matrix is given by

$$\boldsymbol{V} = (\boldsymbol{\Gamma}'\boldsymbol{W}\boldsymbol{\Gamma})^{-1}\boldsymbol{\Gamma}'\boldsymbol{W}\boldsymbol{\Sigma}\boldsymbol{W}\boldsymbol{\Gamma}(\boldsymbol{\Gamma}'\boldsymbol{W}\boldsymbol{\Gamma})^{-1} \tag{A.43}$$

where $\boldsymbol{\Sigma}$ is the variance-covariance matrix of the data. Next, $\boldsymbol{\Gamma}$ is the gradient matrix of the population moment vector:

$$\boldsymbol{\Gamma} = \left.\frac{\partial g(\boldsymbol{\Theta}; \boldsymbol{\chi}_0)}{\partial \boldsymbol{\Theta}'}\right|_{\boldsymbol{\Theta}=\boldsymbol{\Theta}_0} \tag{A.44}$$

and

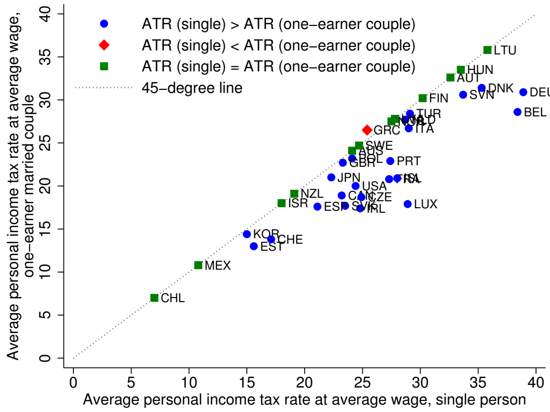
$$\boldsymbol{W} = \underset{n\to\infty}{\text{plim}}\,\widehat{\boldsymbol{W}}_n \tag{A.45}$$

If $\boldsymbol{W} = \boldsymbol{\Sigma}^{-1}$, then

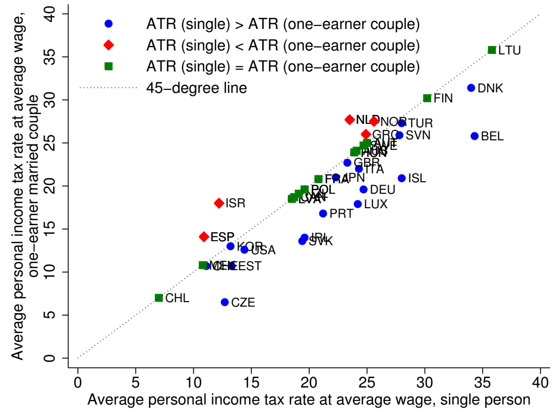
$$\boldsymbol{V} = \left(\boldsymbol{\Gamma}'\boldsymbol{\Sigma}^{-1}\boldsymbol{\Gamma}\right)^{-1} \tag{A.46}$$

When $\widehat{\boldsymbol{W}}_n$ converges to $\boldsymbol{\Sigma}^{-1}$, the weighting matrix is asymptotically efficient. As Altonji and Segal (1996) emphasize, the optimal weighting matrix can suffer from the small-sample bias, and the correlation between sampling errors in the second moments and the sample weighting matrix generates bias in the optimal minimum distance estimator. I use the weighting matrix that contains the diagonal elements of $\boldsymbol{\Sigma}$ and zeros off the diagonal. I estimate matrices $\boldsymbol{\Gamma}$ and $\boldsymbol{W}$ using their sample analogs.

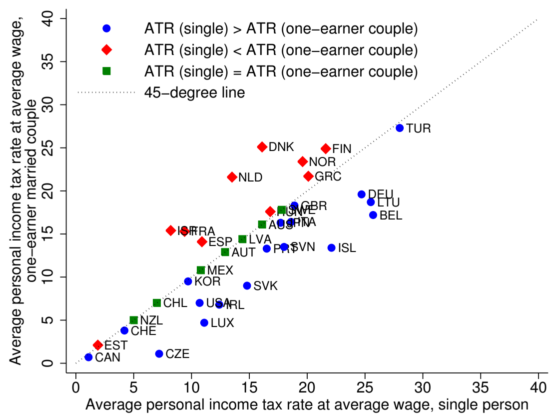
A.4 Additional Figures



(a) Households without children (with transfers)



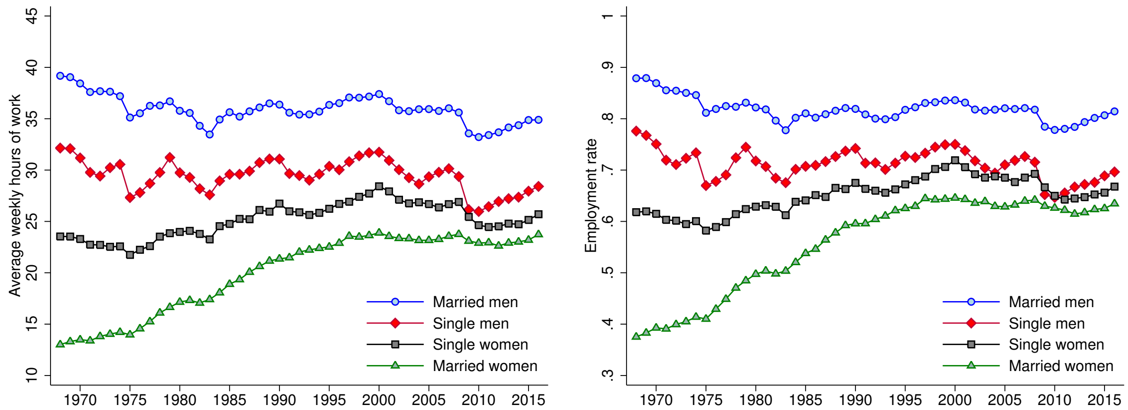
(b) Households with two children (with transfers)



(c) Households with two children (no transfers)

Figure A.1: Average Income Tax Rates at Average Wage for Singles and Married Couples by Country

Notes: I use the data from the OECD Tax Database (Table I.6) for year 2020. The figure reports average personal income tax rates for single individuals and one-earner married couples without children (panel (a)) and with two children (panels (b) and (c)), calculated at the average wage. The tax rates in panels (a) and (b) are inclusive of universal family cash transfers. The tax rates in panel (c) are exclusive of universal family cash transfers.

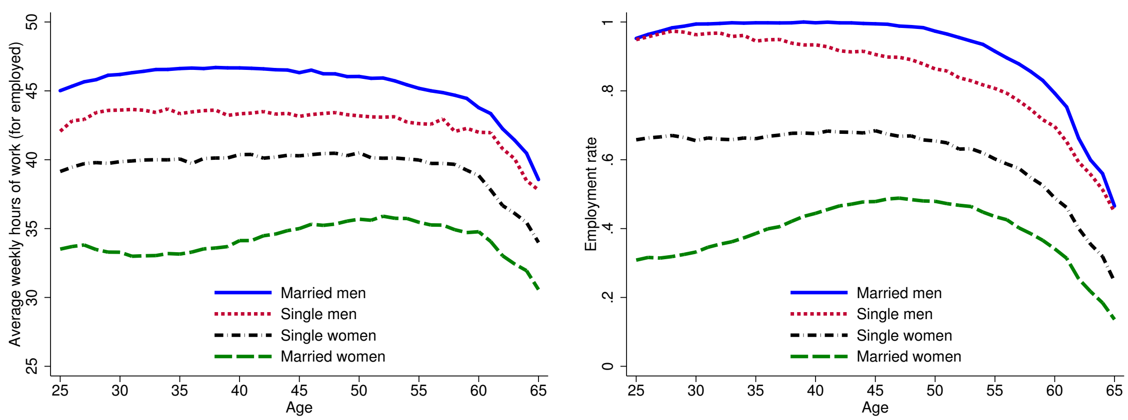


(a) Average weekly hours of work

(b) Employment rate

Figure A.2: Labor Supply Trends by Gender and Marital Status in the United States

Notes: I use the CPS data for individuals aged 25-65. An individual is defined as employed if he/she worked a positive number of hours during the previous week. I drop those who are employed but who report working less than 5 hours, those who report working more than 80 hours, and those who earn less than half of the federal minimum wage.

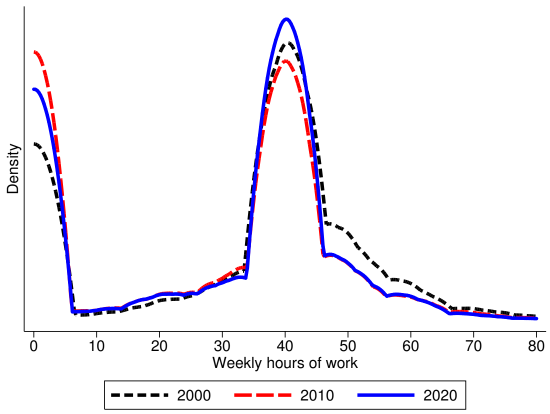


(a) Average weekly hours of work (for employed)

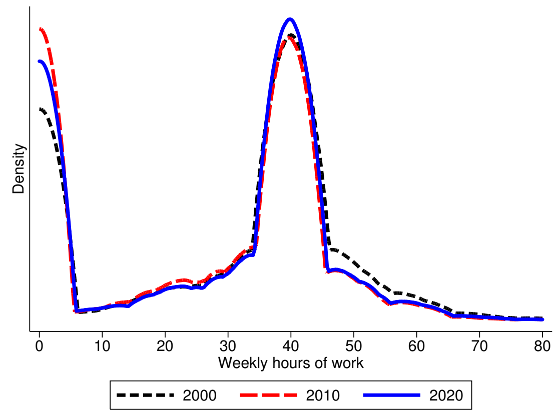
(b) Employment rate

Figure A.3: Lifecycle Profiles by Gender and Marital Status in the United States

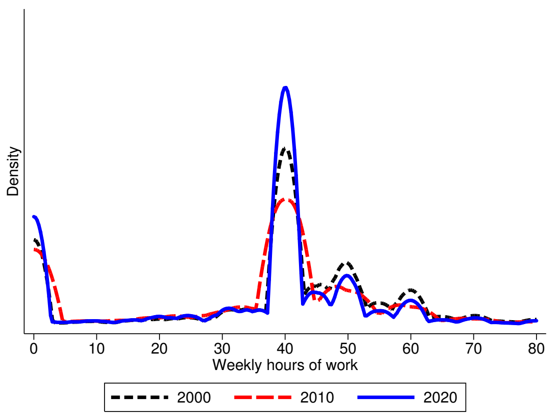
Notes: I use the CPS data for individuals aged 25-65. An individual is defined as employed if he/she worked a positive number of hours during the previous week. I drop those who are employed but who report working less than 5 hours, those who report working more than 80 hours, and those who earn less than half of the federal minimum wage. The profiles are constructed by cleaning cohort effects following the usual procedure in the literature.



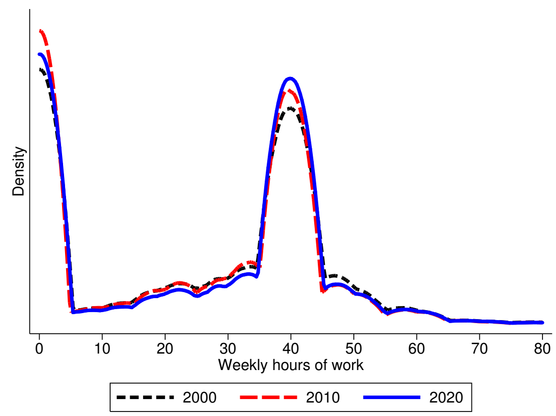
(a) Single men



(b) Single women



(c) Married men



(d) Married women

Figure A.4: Distribution of Weekly Hours of Work by Gender and Marital Status

NOTES: To construct the figures, I use the CPS data on the reported hours worked during the previous week by individuals aged 25-65.

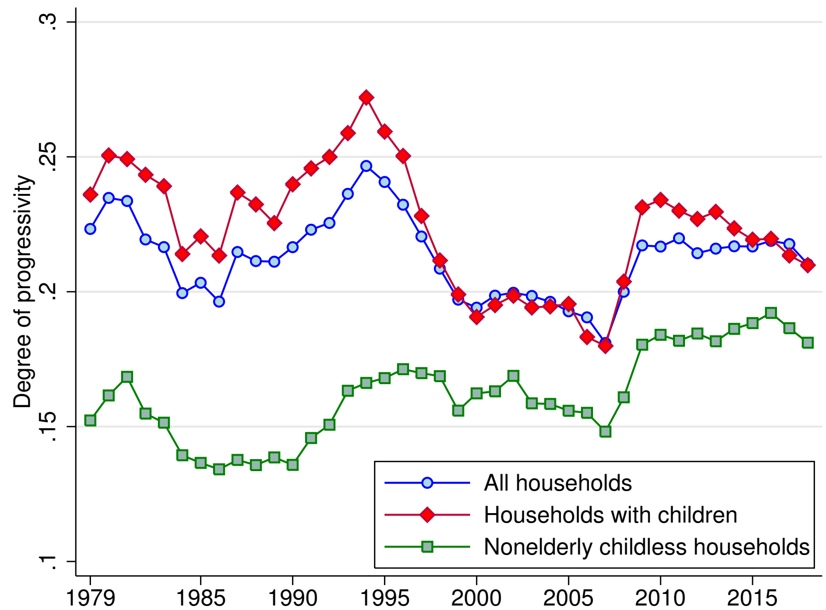


Figure A.5: Tax Progressivity for U.S. Households with and without Children

NOTES: Progressivity of the tax and transfer system is measured by parameter τ from function (1.1). I estimate it using the data from the Congressional Budget Office between 1979 and 2018.

A.5 Additional Tables

Table A.1: Age-Dependent Probability of Dying and Survival Probability in the United States, 2014

Age a	Probability of dying	Survival probability ζ_a
65-66	0.0125	0.9875
66-67	0.0134	0.9866
67-68	0.0144	0.9856
68-69	0.0156	0.9844
69-70	0.0170	0.9830
70-71	0.0187	0.9813
71-72	0.0205	0.9795
72-73	0.0226	0.9774
73-74	0.0247	0.9753
74-75	0.0270	0.9730
75-76	0.0295	0.9705
76-77	0.0323	0.9677
77-78	0.0357	0.9643
78-79	0.0395	0.9605
79-80	0.0439	0.9561
80-81	0.0488	0.9512
81-82	0.0540	0.9460
82-83	0.0597	0.9403
83-84	0.0664	0.9336
84-85	0.0739	0.9261
85-86	0.0820	0.9180
86-87	0.0915	0.9085
87-88	0.1020	0.8980
88-89	0.1135	0.8865
89-90	0.1260	0.8740
90-91	0.1395	0.8605
91-92	0.1540	0.8460
92-93	0.1696	0.8304
93-94	0.1861	0.8139
94-95	0.2036	0.7964
95-96	0.2220	0.7780
96-97	0.2412	0.7588
97-98	0.2611	0.7389
98-99	0.2815	0.7185
99-100	0.3024	0.6976
100+	1	0

Appendix B

Appendix to Chapter 2

B.1 Proofs

B.1.1 Proof of Proposition 2.1

This proof extends Eissa et al. (2008) to the framework with couples. First, differentiate the compensated labor supply functions for dual-earner and single-earner couples with respect to θ:

$$\frac{d\tilde{h}_i^{m,2}}{d\theta} = -\sum_{j=m,f} \frac{\partial \tilde{h}_i^{m,2}\left((1-\tau_i^m)w_i^m, (1-\tau_i^f)w_i^f, v_i\right)}{\partial\left(\left(1-\tau_i^j\right)w_i^j\right)} w_i^j \frac{d\tau_i^j}{d\theta} =$$
$$-\sum_{j=m,f}\left(\frac{\partial \tilde{h}_i^{m,2}}{\partial\left(1-\tau_i^j\right)}\cdot\frac{1-\tau_i^j}{\tilde{h}_i^{m,2}}\right)\cdot\frac{\tilde{h}_i^{m,2}}{1-\tau_i^j}\cdot\frac{d\tau_i^j}{d\theta} = -\left(\varepsilon_i^{m,2}\frac{\tilde{h}_i^{m,2}}{1-\tau_i^m}\cdot\frac{d\tau_i^m}{d\theta} + \varepsilon_i^{mf}\frac{\tilde{h}_i^{m,2}}{1-\tau_i^f}\cdot\frac{d\tau_i^f}{d\theta}\right) \tag{B.1}$$

and, following similar arguments,

$$\frac{d\tilde{h}_i^f}{d\theta} = -\left(\varepsilon_i^f\frac{\tilde{h}_i^f}{1-\tau_i^f}\cdot\frac{d\tau_i^f}{d\theta} + \varepsilon_i^{fm}\frac{\tilde{h}_i^f}{1-\tau_i^m}\cdot\frac{d\tau_i^m}{d\theta}\right) \tag{B.2}$$

$$\frac{d\tilde{h}_i^{m,1}}{d\theta} = -\varepsilon_i^{m,1}\frac{\tilde{h}_i^{m,1}}{1-\tau_i^m}\cdot\frac{d\tau_i^m}{d\theta} \tag{B.3}$$

Next, I derive the expression for $dF_i\left(\tilde{q}_i\right)/d\theta = \left(\partial F_i\left(\tilde{q}_i\right)/\partial\tilde{q}_i\right)\cdot\left(d\tilde{q}_i/d\theta\right)$. First, differentiate the expression for threshold $\tilde{q}_i$, (2.16), with respect to θ:

$$\frac{d\tilde{q}_i}{d\theta} = \frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial\tilde{c}_i^2}\cdot\frac{d\tilde{c}_i^2}{d\theta} + \frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial\tilde{h}_i^{m,2}}\cdot\frac{d\tilde{h}_i^{m,2}}{d\theta} + \frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial\tilde{h}_i^f}\cdot\frac{d\tilde{h}_i^f}{d\theta} -$$
$$\frac{\partial v_i\left(\tilde{c}_i^1, \tilde{h}_i^{m,1}, 0\right)}{\partial\tilde{c}_i^1}\cdot\frac{d\tilde{c}_i^1}{d\theta} - \frac{\partial v_i\left(\tilde{c}_i^1, \tilde{h}_i^{m,1}, 0\right)}{\partial\tilde{h}_i^{m,1}}\cdot\frac{d\tilde{h}_i^{m,1}}{d\theta} \tag{B.4}$$

Next, differentiate the equation that connects compensated consumption in dual-earner and single-earner couples, (2.15), with respect to θ:

$$\frac{d\tilde{c}_i^2}{d\theta} = \frac{d\tilde{c}_i^1}{d\theta} + w_i^m \left(\frac{d\tilde{h}_i^{m,2}}{d\theta} - \frac{d\tilde{h}_i^{m,1}}{d\theta} \right) + w_i^f \frac{d\tilde{h}_i^f}{d\theta} - \left[\frac{\partial T\left(w_i^m \tilde{h}_i^{m,2}, w_i^f \tilde{h}_i^f, \theta\right)}{\partial \left(w_i^m \tilde{h}_i^{m,2}\right)} \cdot \frac{d\tilde{h}_i^{m,2}}{d\theta} w_i^m + \right.$$
$$\frac{\partial T\left(w_i^m \tilde{h}_i^{m,2}, w_i^f \tilde{h}_i^f, \theta\right)}{\partial \left(w_i^f \tilde{h}_i^f\right)} \cdot \frac{d\tilde{h}_i^f}{d\theta} w_i^f + \frac{dT\left(w_i^m \tilde{h}_i^{m,2}, w_i^f \tilde{h}_i^f, \theta\right)}{d\theta} -$$
$$\left. \frac{\partial T\left(w_i^m \tilde{h}_i^{m,1}, 0, \theta\right)}{\partial \left(w_i^m \tilde{h}_i^{m,1}\right)} \cdot \frac{d\tilde{h}_i^{m,1}}{d\theta} w_i^m - \frac{dT\left(w_i^m \tilde{h}_i^{m,1}, 0, \theta\right)}{d\theta} \right] =$$
$$\frac{d\tilde{c}_i^1}{d\theta} + (1 - \tau_i^m)\, w_i^m \left(\frac{d\tilde{h}_i^{m,2}}{d\theta} - \frac{d\tilde{h}_i^{m,1}}{d\theta} \right) + \left(1 - \tau_i^f\right) w_i^f \frac{d\tilde{h}_i^f}{d\theta} - \frac{da_i}{d\theta} \left[w_i^m \left(\tilde{h}_i^{m,2} - \tilde{h}_i^{m,1} \right) + w_i^f \tilde{h}_i^f \right] \tag{B.5}$$

where I denote the reform-induced change in the effective participation tax rate as

$$\frac{da_i}{d\theta} \equiv \frac{dT\left(w_i^m \tilde{h}_i^{m,2}, w_i^f \tilde{h}_i^f, \theta\right)/d\theta - dT\left(w_i^m \tilde{h}_i^{m,1}, 0, \theta\right)/d\theta}{w_i^m \left(\tilde{h}_i^{m,2} - \tilde{h}_i^{m,1}\right) + w_i^f \tilde{h}_i^f}$$

Next, I plug (B.5) into (B.4) and use the first-order conditions from the expenditure minimization problem for dual-earner and single-earner couples to get

$$\frac{d\tilde{q}_i}{d\theta} = \left(\frac{d\tilde{c}_i^1}{d\theta} - (1 - \tau_i^m)\, w_i^m \frac{d\tilde{h}_i^{m,1}}{d\theta} \right) \left(\frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial \tilde{c}_i^2} - \frac{\partial v_i\left(\tilde{c}_i^1, \tilde{h}_i^{m,1}, 0\right)}{\partial \tilde{c}_i^1} \right) -$$
$$\frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial \tilde{c}_i^2} \cdot \frac{da_i}{d\theta} \left[w_i^m \left(\tilde{h}_i^{m,2} - \tilde{h}_i^{m,1} \right) + w_i^f \tilde{h}_i^f \right]$$

Notice that the first multiplier in the first term is equal to zero, and therefore I obtain

$$\frac{d\tilde{q}_i}{d\theta} = - \frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial \tilde{c}_i^2} \cdot \frac{da_i}{d\theta} \left[w_i^m \left(\tilde{h}_i^{m,2} - \tilde{h}_i^{m,1} \right) + w_i^f \tilde{h}_i^f \right] \tag{B.6}$$

Plugging (B.6) into $dF_i(\tilde{q}_i)/d\theta = (\partial F_i(\tilde{q}_i)/\partial \tilde{q}_i) \cdot (d\tilde{q}_i/d\theta)$, I get

$$\frac{dF_i(\tilde{q}_i)}{d\theta} = -\frac{\partial F_i(\tilde{q}_i)}{\partial \tilde{q}_i} \cdot \frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial \tilde{c}_i^2} \cdot \frac{da_i}{d\theta}\left[w_i^m\left(\tilde{h}_i^{m,2} - \tilde{h}_i^{m,1}\right) + w_i^f \tilde{h}_i^f\right] \tag{B.7}$$

From the definition of the compensated participation elasticity, (2.19),

$$\eta_i = \frac{\partial F_i(\tilde{q}_i)}{\partial \tilde{q}_i} \cdot \frac{d\tilde{q}_i}{d(1-a_i)} \cdot \frac{1-a_i}{F_i(\tilde{q}_i)} = -\frac{\partial F_i(\tilde{q}_i)}{\partial \tilde{q}_i} \cdot \frac{d\tilde{q}_i}{da_i} \cdot \frac{1-a_i}{F_i(\tilde{q}_i)} \tag{B.8}$$

To get the expression for $d\tilde{q}_i/da_i$, I use (B.6):

$$\frac{d\tilde{q}_i}{da_i} = \frac{d\tilde{q}_i/d\theta}{da_i/d\theta} = -\frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial \tilde{c}_i^2}\left[w_i^m\left(\tilde{h}_i^{m,2} - \tilde{h}_i^{m,1}\right) + w_i^f \tilde{h}_i^f\right] \tag{B.9}$$

Plugging (B.9) into (B.8), we obtain:

$$\eta_i = \frac{\partial F_i(\tilde{q}_i)}{\partial \tilde{q}_i} \cdot \frac{1-a_i}{F_i(\tilde{q}_i)} \cdot \frac{\partial v_i\left(\tilde{c}_i^2, \tilde{h}_i^{m,2}, \tilde{h}_i^f\right)}{\partial \tilde{c}_i^2}\left[w_i^m\left(\tilde{h}_i^{m,2} - \tilde{h}_i^{m,1}\right) + w_i^f \tilde{h}_i^f\right] \tag{B.10}$$

Next, I plug (B.10) into (B.7), and obtain

$$\frac{dF_i(\tilde{q}_i)}{d\theta} = -\frac{F_i(\tilde{q}_i)}{1-a_i} \cdot \frac{da_i}{d\theta}\eta_i \tag{B.11}$$

Finally, I plug (B.1)-(B.3) and (B.11) into (2.28), and obtain

$$\begin{aligned}\frac{dD}{d\theta} = \sum_{i=1}^{N}\Bigg[\left(\varepsilon_i^{m,2}\frac{\tau_i^m}{1-\tau_i^m} \cdot \frac{d\tau_i^m}{d\theta} + \varepsilon_i^{mf}\frac{\tau_i^m}{1-\tau_i^f} \cdot \frac{d\tau_i^f}{d\theta}\right) F_i(\tilde{q}_i)\, w_i^m \tilde{h}_i^{m,2} + \\ \varepsilon_i^{m,1}\frac{\tau_i^m}{1-\tau_i^m} \cdot \frac{d\tau_i^m}{d\theta}\left(1 - F_i(\tilde{q}_i)\right) w_i^m \tilde{h}_i^{m,1} + \left(\varepsilon_i^f\frac{\tau_i^f}{1-\tau_i^f} \cdot \frac{d\tau_i^f}{d\theta} + \varepsilon_i^{fm}\frac{\tau_i^f}{1-\tau_i^m} \cdot \frac{d\tau_i^m}{d\theta}\right) F_i(\tilde{q}_i)\, w_i^f \tilde{h}_i^f + \\ \eta_i \frac{a_i}{1-a_i} \cdot \frac{da_i}{d\theta} F_i(\tilde{q}_i)\left[w_i^m\left(\tilde{h}_i^{m,2} - \tilde{h}_i^{m,1}\right) + w_i^f \tilde{h}_i^f\right]\Bigg]\end{aligned} \tag{B.12}$$

Dividing this expression by aggregate labor income, (2.29), I obtain equation (2.30). This completes the proof of Proposition 2.1. ■

B.1.2 Proof of Proposition 2.2

This proof extends Blomquist and Simula (2019) to the framework with couples. The utility maximization problem of couple is given by

$$\max_{c,y_m,y_f} v\left(c, y_m, y_f, \upsilon_m, \upsilon_f\right) \tag{B.13}$$

$$\text{s.t.} \quad c = y_m + y_f - T\left(y_m, y_f, \theta\right) + I \tag{B.14}$$

where y_m and y_f are taxable incomes of a male and a female, υ_m and υ_f are individual specific preference parameters of a male and a female, and I is lump-sum non-taxable income. As before, θ is a treatment parameter that captures the tax policy reforms. Preference parameters $\boldsymbol{\upsilon} = \left(\upsilon_m, \upsilon_f\right)$ are jointly drawn from continuous distribution Γ. Denote the solution to this problem by $c\left(\upsilon_m, \upsilon_f, \theta, I\right)$, $y_m\left(\upsilon_m, \upsilon_f, \theta, I\right)$, and $y_f\left(\upsilon_m, \upsilon_f, \theta, I\right)$.

Next, to get the compensated functions, I turn to the expenditure minimization problem that is given by

$$\min_{c,y_m,y_f} c - y_m - y_f + T\left(y_m, y_f, \theta\right) - I \tag{B.15}$$

$$\text{s.t.} \quad v\left(c, y_m, y_f, \upsilon_m, \upsilon_f\right) \geq \bar{U} \tag{B.16}$$

where $\bar{U}$ is a fixed level of utility. The solution delivers compensated functions $\tilde{c}\left(\upsilon_m, \upsilon_f, \theta, \bar{U}\right)$, $\tilde{y}_m\left(\upsilon_m, \upsilon_f, \theta, \bar{U}\right)$, and $\tilde{y}_f\left(\upsilon_m, \upsilon_f, \theta, \bar{U}\right)$.

Note that, at the optimum, the following equality holds:

$$v\left(\tilde{c}, \tilde{y}_m, \tilde{y}_f, \upsilon_m, \upsilon_f\right) = \bar{U} \tag{B.17}$$

Using the compensated functions, I write the expenditure function as

$$E\left(\upsilon_m, \upsilon_f, \theta, \bar{U}\right) = \tilde{c} - \tilde{y}_m - \tilde{y}_f + T\left(\tilde{y}_m, \tilde{y}_f, \theta\right) - I \tag{B.18}$$

Next, set $\bar{U}$ to be the indirect utility delivered by the utility maximization problem (B.13)-(B.14). Then the solutions to the expenditure minimization problem and utility maximization problem coincide.

Consistent with (2.24), I use the measure of excess burden based on the equivalent variation:

$$D\left(\upsilon_m,\upsilon_f,\theta,\bar{U}\right)=E\left(\upsilon_m,\upsilon_f,\theta,\bar{U}\right)-E\left(\upsilon_m,\upsilon_f,0,\bar{U}\right)-R\left(\upsilon_m,\upsilon_f,\theta,\bar{U}\right) \tag{B.19}$$

The tax revenue function $R\left(\upsilon_m,\upsilon_f,\theta,\bar{U}\right)$ is given by

$$R\left(\upsilon_m,\upsilon_f,\theta,\bar{U}\right)=T\left(\tilde{y}_m,\tilde{y}_f,\theta\right) \tag{B.20}$$

Aggregate deadweight loss from a tax and transfer system θ is obtained by integrating excess burdens over all couples:

$$D=\int D\left(\upsilon_m,\upsilon_f,\theta,\bar{U}\right)d\Gamma\left(\upsilon_m,\upsilon_f\right) \tag{B.21}$$

Next, plugging (B.20) into (B.19), I obtain

$$D=\int\left[E\left(\upsilon_m,\upsilon_f,\theta,\bar{U}\right)-T\left(\tilde{y}_m,\tilde{y}_f,\theta\right)-E\left(\upsilon_m,\upsilon_f,0,\bar{U}\right)\right]d\Gamma\left(\upsilon_m,\upsilon_f\right) \tag{B.22}$$

Applying the envelope theorem to (B.18), I obtain $dE\left(\upsilon_m,\upsilon_f,\theta,\bar{U}\right)/d\theta=\partial T\left(\tilde{y}_m,\tilde{y}_f,\theta\right)/\partial\theta$, i.e. the small tax reform affects the expenditure function only through mechanical revenue effect. Differentiating aggregate excess burden (B.22) with respect to parameter θ and using the result from the envelope theorem, I get

$$\frac{dD}{d\theta}=-\int\left[\frac{\partial T\left(\tilde{y}_m,\tilde{y}_f,\theta\right)}{\partial\tilde{y}_m}\cdot\frac{d\tilde{y}_m}{d\theta}+\frac{\partial T\left(\tilde{y}_m,\tilde{y}_f,\theta\right)}{\partial\tilde{y}_f}\cdot\frac{d\tilde{y}_f}{d\theta}\right]d\Gamma\left(\upsilon_m,\upsilon_f\right) \tag{B.23}$$

Next, I rewrite the expression for marginal deadweight loss in terms of the curvatures of the indifference curve and the tax function. Consider a small reform captured by $d\theta\approx 0$. In the expenditure minimization problem, assume that constraint (B.16) is binding:

$$\upsilon\left(c,y_m,y_f,\upsilon_m,\upsilon_f\right)=\bar{U} \tag{B.24}$$

Define function $c = \psi\left(y_m, y_f, \upsilon_m, \upsilon_f, \bar{U}\right)$, and plug it into the objective (B.15):

$$\min_{y_m, y_f} \psi\left(y_m, y_f, \upsilon_m, \upsilon_f, \bar{U}\right) - y_m - y_f + T\left(y_m, y_f, \theta\right) - I \tag{B.25}$$

From (B.25), I get the following first-order conditions:

$$\frac{\partial\psi\left(\tilde{y}_m, \tilde{y}_f, \upsilon_m, \upsilon_f, \bar{U}\right)}{\partial\tilde{y}_j} - 1 + \frac{\partial T\left(\tilde{y}_m, \tilde{y}_f, \theta\right)}{\partial\tilde{y}_j} = 0, \qquad j = m, f \tag{B.26}$$

Differentiating (B.26) with respect to policy parameter θ, I obtain

$$\frac{\partial^2\psi\left(\tilde{y}_m, \tilde{y}_f, \upsilon_m, \upsilon_f, \bar{U}\right)}{\partial\left(\tilde{y}_m\right)^2}\frac{d\tilde{y}_m}{d\theta} + \frac{\partial^2\psi\left(\tilde{y}_m, \tilde{y}_f, \upsilon_m, \upsilon_f, \bar{U}\right)}{\partial\tilde{y}_m\partial\tilde{y}_f}\frac{d\tilde{y}_f}{d\theta} + \frac{\partial^2 T\left(\tilde{y}_m, \tilde{y}_f, \theta\right)}{\partial\tilde{y}_m\partial\theta} + \frac{\partial^2 T\left(\tilde{y}_m, \tilde{y}_f, \theta\right)}{\partial\left(\tilde{y}_m\right)^2}\frac{d\tilde{y}_m}{d\theta} + \frac{\partial^2 T\left(\tilde{y}_m, \tilde{y}_f, \theta\right)}{\partial\tilde{y}_m\partial\tilde{y}_f}\frac{d\tilde{y}_f}{d\theta} = 0 \tag{B.27}$$

$$\frac{\partial^2\psi\left(\tilde{y}_m, \tilde{y}_f, \upsilon_m, \upsilon_f, \bar{U}\right)}{\partial\left(\tilde{y}_f\right)^2}\frac{d\tilde{y}_f}{d\theta} + \frac{\partial^2\psi\left(\tilde{y}_m, \tilde{y}_f, \upsilon_m, \upsilon_f, \bar{U}\right)}{\partial\tilde{y}_m\partial\tilde{y}_f}\frac{d\tilde{y}_m}{d\theta} + \frac{\partial^2 T\left(\tilde{y}_m, \tilde{y}_f, \theta\right)}{\partial\tilde{y}_f\partial\theta} + \frac{\partial^2 T\left(\tilde{y}_m, \tilde{y}_f, \theta\right)}{\partial\left(\tilde{y}_f\right)^2}\frac{d\tilde{y}_f}{d\theta} + \frac{\partial^2 T\left(\tilde{y}_m, \tilde{y}_f, \theta\right)}{\partial\tilde{y}_m\partial\tilde{y}_f}\frac{d\tilde{y}_m}{d\theta} = 0 \tag{B.28}$$

Denote $\psi''_{ij} \equiv \partial^2\psi(\cdot)/\partial\tilde{y}_i\partial\tilde{y}_j$, $T''_{ij} \equiv \partial^2 T(\cdot)/\partial\tilde{y}_i\partial\tilde{y}_j$, and $T''_{i\theta} \equiv \partial^2 T(\cdot)/\partial\tilde{y}_i\partial\theta$. Solving for $d\tilde{y}_m/d\theta$ and $d\tilde{y}_f/d\theta$ from equations (B.27) and (B.28), I get the expressions in terms of curvatures of the indifference curve and tax function:

$$\frac{d\tilde{y}_m}{d\theta} = \frac{\left(\psi''_{mf} + T''_{mf}\right)T''_{f\theta} - \left(\psi''_{ff} + T''_{ff}\right)T''_{m\theta}}{\left(\psi''_{mm} + T''_{mm}\right)\left(\psi''_{ff} + T''_{ff}\right) - \left(\psi''_{mf} + T''_{mf}\right)^2} \tag{B.29}$$

$$\frac{d\tilde{y}_f}{d\theta} = \frac{\left(\psi''_{mf} + T''_{mf}\right)T''_{m\theta} - \left(\psi''_{mm} + T''_{mm}\right)T''_{f\theta}}{\left(\psi''_{mm} + T''_{mm}\right)\left(\psi''_{ff} + T''_{ff}\right) - \left(\psi''_{mf} + T''_{mf}\right)^2} \tag{B.30}$$

Denoting $T'_i \equiv \partial T(\cdot)/\partial y_i$ and plugging (B.29) and (B.30) into (B.23), I obtain the expression for reform-induced efficiency loss under nonlinear taxation of couples:

$$\frac{dD}{d\theta} = -\int \left[\frac{T'_m \left[\left(\psi''_{mf} + T''_{mf} \right) T''_{f\theta} - \left(\psi''_{ff} + T''_{ff} \right) T''_{m\theta} \right]}{\left(\psi''_{mm} + T''_{mm} \right) \left(\psi''_{ff} + T''_{ff} \right) - \left(\psi''_{mf} + T''_{mf} \right)^2} + \frac{T'_f \left[\left(\psi''_{mf} + T''_{mf} \right) T''_{m\theta} - \left(\psi''_{mm} + T''_{mm} \right) T''_{f\theta} \right]}{\left(\psi''_{mm} + T''_{mm} \right) \left(\psi''_{ff} + T''_{ff} \right) - \left(\psi''_{mf} + T''_{mf} \right)^2} \right] d\Gamma \left(\upsilon_m, \upsilon_f \right) \quad \text{(B.31)}$$

Linearized Tax Function

Given $(\upsilon_m, \upsilon_f, \theta, I)$, a couple solve the problem (B.13)-(B.14), and I denote the solution by $c^* = c\left(\upsilon_m, \upsilon_f, \theta, I\right)$, $y_m^* = y_m\left(\upsilon_m, \upsilon_f, \theta, I\right)$, and $y_f^* = y_f\left(\upsilon_m, \upsilon_f, \theta, I\right)$. I linearize the tax system, so that now it is described by proportional tax rates $\tau_m = \partial T\left(y_m, y_f, \theta\right) / \partial y_m$ and $\tau_f = \partial T\left(y_m, y_f, \theta\right) / \partial y_f$ and a lump-sum component. Namely,

$$T^L\left(y_m, y_f, \tau_m, \tau_f\right) = \tau_m(\theta) y_m + \tau_f(\theta) y_f + T^* \quad \text{(B.32)}$$

This linearized tax system delivers $\left(c^*, y_m^*, y_f^*\right)$ as a solution if I set $T^* = y_m^* + y_f^* - c^* - \tau_m y_m^* + \tau_f y_f^* + I$. To simplify notation, I omit explicit dependence of τ_m and τ_f on parameter θ. Under linearized tax system, the couple's budget constraint is given by

$$c = \left(1 - \tau_m\right) y_m + \left(1 - \tau_f\right) y_f + I - T^* \quad \text{(B.33)}$$

Denote the solution to the problem with a linearized tax function, given by (B.13) and (B.33), by $c^L\left(\upsilon_m, \upsilon_f, \tau_m, \tau_f, I - T^*\right)$, $y_m^L\left(\upsilon_m, \upsilon_f, \tau_m, \tau_f, I - T^*\right)$, and $y_f^L\left(\upsilon_m, \upsilon_f, \tau_m, \tau_f, I - T^*\right)$. By construction, it coincides with $\left(c^*, y_m^*, y_f^*\right)$.

Next, solving the expenditure minimization problem with a linearized tax function, I get the compensated functions $\tilde{c}^L\left(\upsilon_m, \upsilon_f, \tau_m, \tau_f, \bar{U}\right)$, $\tilde{y}_m^L\left(\upsilon_m, \upsilon_f, \tau_m, \tau_f, \bar{U}\right)$, and $\tilde{y}_f^L\left(\upsilon_m, \upsilon_f, \tau_m, \tau_f, \bar{U}\right)$. Using the expression for marginal deadweight loss (B.23), I obtain

$$\frac{dD^L}{d\theta} = -\int \left[\frac{\partial T^L\left(\tilde{y}_m^L, \tilde{y}_f^L, \tau_m, \tau_f\right)}{\partial \tilde{y}_m^L} \cdot \frac{d\tilde{y}_m^L}{d\theta} + \frac{\partial T^L\left(\tilde{y}_m^L, \tilde{y}_f^L, \tau_m, \tau_f\right)}{\partial \tilde{y}_f^L} \cdot \frac{d\tilde{y}_f^L}{d\theta} \right] d\Gamma\left(\upsilon_m, \upsilon_f\right) \quad \text{(B.34)}$$

Now, I rewrite this expression for reform-induced efficiency loss in terms of the curvatures of the indifference curve and tax function. Under a linearized tax function, it is true that $\left(T^L\right)''_{ij} \equiv \partial^2 T^L(\cdot)/\partial\tilde{y}_i^L\partial\tilde{y}_j^L = 0$. Furthermore, since, by construction, $\left(T^L\right)'_i = T'_i$, then it is also true that $\left(T^L\right)''_{i\theta} = T''_{i\theta}$. Therefore, using these results in (B.29) and (B.30), I obtain

$$\frac{d\tilde{y}_m^L}{d\theta} = \frac{\psi''_{mf}T''_{f\theta} - \psi''_{ff}T''_{m\theta}}{\psi''_{mm}\psi''_{ff} - \left(\psi''_{mf}\right)^2} \tag{B.35}$$

$$\frac{d\tilde{y}_f^L}{d\theta} = \frac{\psi''_{mf}T''_{m\theta} - \psi''_{mm}T''_{f\theta}}{\psi''_{mm}\psi''_{ff} - \left(\psi''_{mf}\right)^2} \tag{B.36}$$

Plugging (B.35) and (B.36) into (B.34), I obtain the expression for marginal deadweight loss under linearized tax function:

$$\frac{dD^L}{d\theta} = -\int \left[\frac{T'_m\left(\psi''_{mf}T''_{f\theta} - \psi''_{ff}T''_{m\theta}\right)}{\psi''_{mm}\psi''_{ff} - \left(\psi''_{mf}\right)^2} + \frac{T'_f\left(\psi''_{mf}T''_{m\theta} - \psi''_{mm}T''_{f\theta}\right)}{\psi''_{mm}\psi''_{ff} - \left(\psi''_{mf}\right)^2}\right] d\Gamma\left(\upsilon_m, \upsilon_f\right) \tag{B.37}$$

This completes the proof of Proposition 2.2. ■

B.1.3 Proof of Proposition B.1

Before proving Proposition 2.3, first, I state and prove Proposition B.1 that characterizes the expressions for marginal deadweight losses under joint and separate taxation of spousal incomes.

Proposition B.1 (Efficiency Loss with HSV Tax Function). *Under joint taxation of spousal incomes, described by (2.39), efficiency loss for (υ_m, υ_f)-couple from a small change in tax progressivity $d\theta \approx 0$ is given by*

$$\frac{dD_{joint}(\upsilon_m,\upsilon_f)}{d\theta} = \left[1-\lambda^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}(\upsilon_m+\upsilon_f)^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\times \frac{\left[\lambda(1-\theta)^{1-\sigma-\theta}(\upsilon_m+\upsilon_f)^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma+\theta}\left[1+\frac{(1-\theta)\log\left(\lambda(1-\theta)(\upsilon_m+\upsilon_f)^{\sigma}\right)}{\sigma+\theta}\right]$$

Under joint taxation of spousal incomes and linearized tax function, efficiency loss for (υ_m, υ_f)-couple from a small reform $d\theta \approx 0$ is given by

$$\frac{dD^{L}_{joint}(\upsilon_m,\upsilon_f)}{d\theta} = \left[1-\lambda^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}(\upsilon_m+\upsilon_f)^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\times \frac{\left[\lambda(1-\theta)^{1-\sigma-\theta}(\upsilon_m+\upsilon_f)^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma}\left[1+\frac{(1-\theta)\log\left(\lambda(1-\theta)(\upsilon_m+\upsilon_f)^{\sigma}\right)}{\sigma+\theta}\right]$$

where λ in both expressions above is given by

$$\lambda = (1-g)^{\frac{\sigma+\theta}{\sigma}}(1-\theta)^{\frac{\theta}{\sigma}}\left[\frac{\int(\upsilon_m+\upsilon_f)^{\frac{\sigma}{\sigma+\theta}}\,d\Gamma(\upsilon_m,\upsilon_f)}{\int(\upsilon_m+\upsilon_f)^{\frac{\sigma(1-\theta)}{\sigma+\theta}}\,d\Gamma(\upsilon_m,\upsilon_f)}\right]^{\frac{\sigma+\theta}{\sigma}}$$

Under separate taxation of spousal incomes, described by (2.40), efficiency loss for (υ_m, υ_f)-

couple from a small change in tax progressivity $d\theta \approx 0$ is given by

$$\frac{dD_{sep}\left(\upsilon_m,\upsilon_f\right)}{d\theta} =$$

$$\left[1-\tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_m^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\frac{\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_m^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma+\theta}\left[1+\frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_m^{\sigma}\right)}{\sigma+\theta}\right]+$$

$$\left[1-\tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_f^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\frac{\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_f^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma+\theta}\left[1+\frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_f^{\sigma}\right)}{\sigma+\theta}\right]$$

Under separate taxation of spousal incomes and linearized tax function, efficiency loss for (υ_m,υ_f)-couple from a small reform $d\theta \approx 0$ is given by

$$\frac{dD^L_{sep}\left(\upsilon_m,\upsilon_f\right)}{d\theta} =$$

$$\left[1-\tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_m^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\frac{\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_m^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma}\left[1+\frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_m^{\sigma}\right)}{\sigma+\theta}\right]+$$

$$\left[1-\tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_f^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\frac{\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_f^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma}\left[1+\frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_f^{\sigma}\right)}{\sigma+\theta}\right]$$

where $\tilde{\lambda}$ in both expressions above is given by

$$\tilde{\lambda} = (1-g)^{\frac{\sigma+\theta}{\sigma}}(1-\theta)^{\frac{\theta}{\sigma}}\left[\frac{\int\left(\upsilon_m^{\frac{\sigma}{\sigma+\theta}}+\upsilon_f^{\frac{\sigma}{\sigma+\theta}}\right)d\Gamma\left(\upsilon_m,\upsilon_f\right)}{\int\left(\upsilon_m^{\frac{\sigma(1-\theta)}{\sigma+\theta}}+\upsilon_f^{\frac{\sigma(1-\theta)}{\sigma+\theta}}\right)d\Gamma\left(\upsilon_m,\upsilon_f\right)}\right]^{\frac{\sigma+\theta}{\sigma}}$$

Proof.

Joint Taxation of Spouses

The problem of couple characterized by preference parameters (υ_m,υ_f) is given by

$$\max_{c,y_m,y_f} c-\frac{\upsilon_m}{\sigma+1}\left(\frac{y_m}{\upsilon_m}\right)^{\sigma+1}-\frac{\upsilon_f}{\sigma+1}\left(\frac{y_f}{\upsilon_f}\right)^{\sigma+1} \tag{B.38}$$

$$\text{s.t.} \quad c=\lambda\left(y_m+y_f\right)^{1-\theta} \tag{B.39}$$

Plugging (B.39) into (B.38) and maximizing with respect to y_m and y_f, I obtain the following first-order conditions:

$$\left(\frac{y_m}{\upsilon_m}\right)^{\sigma} = \lambda(1-\theta)\left(y_m + y_f\right)^{-\theta} \tag{B.40}$$

$$\left(\frac{y_f}{\upsilon_f}\right)^{\sigma} = \lambda(1-\theta)\left(y_m + y_f\right)^{-\theta} \tag{B.41}$$

Then, using $y_m/\upsilon_m = y_f/\upsilon_f$, derive the expressions for the optimal taxable income:

$$\tilde{y}_m = \lambda^{\frac{1}{\sigma+\theta}}(1-\theta)^{\frac{1}{\sigma+\theta}}\left(\upsilon_m + \upsilon_f\right)^{-\frac{\theta}{\sigma+\theta}}\upsilon_m \tag{B.42}$$

$$\tilde{y}_f = \lambda^{\frac{1}{\sigma+\theta}}(1-\theta)^{\frac{1}{\sigma+\theta}}\left(\upsilon_m + \upsilon_f\right)^{-\frac{\theta}{\sigma+\theta}}\upsilon_f \tag{B.43}$$

Plugging these expressions into (B.39), I obtain the optimal consumption:

$$\tilde{c} = \lambda^{\frac{\sigma+1}{\sigma+\theta}}(1-\theta)^{\frac{1-\theta}{\sigma+\theta}}\left(\upsilon_m + \upsilon_f\right)^{\frac{\sigma(1-\theta)}{\sigma+\theta}} \tag{B.44}$$

Given the quasilinear preferences, the income effect on taxable income is zero, and hence the Marshallian and Hicksian functions coincide. Next, using (B.42) and (B.43), I obtain the compensated tax revenue function:

$$\begin{aligned} T\left(\tilde{y}_m, \tilde{y}_f, \theta\right) &= \tilde{y}_m + \tilde{y}_f - \lambda\left(\tilde{y}_m + \tilde{y}_f\right)^{1-\theta} = \\ &\lambda^{\frac{1}{\sigma+\theta}}(1-\theta)^{\frac{1}{\sigma+\theta}}\left(\upsilon_m + \upsilon_f\right)^{\frac{\sigma}{\sigma+\theta}} - \lambda^{\frac{\sigma+1}{\sigma+\theta}}(1-\theta)^{\frac{1-\theta}{\sigma+\theta}}\left(\upsilon_m + \upsilon_f\right)^{\frac{\sigma(1-\theta)}{\sigma+\theta}} \end{aligned} \tag{B.45}$$

Differentiating the compensated taxable income functions $\tilde{y}_m$ and $\tilde{y}_f$ with respect to the tax progressivity parameter θ, I get

$$\frac{d\tilde{y}_m}{d\theta} = -\upsilon_m\left[\frac{\lambda(1-\theta)}{\left(\upsilon_m + \upsilon_f\right)^{\theta}}\right]^{\frac{1}{\sigma+\theta}}\left[\frac{1}{(1-\theta)(\sigma+\theta)} + \frac{\log\left(\lambda(1-\theta)\left(\upsilon_m + \upsilon_f\right)^{\sigma}\right)}{(\sigma+\theta)^2}\right] \tag{B.46}$$

$$\frac{d\tilde{y}_f}{d\theta} = -\upsilon_f\left[\frac{\lambda(1-\theta)}{\left(\upsilon_m + \upsilon_f\right)^{\theta}}\right]^{\frac{1}{\sigma+\theta}}\left[\frac{1}{(1-\theta)(\sigma+\theta)} + \frac{\log\left(\lambda(1-\theta)\left(\upsilon_m + \upsilon_f\right)^{\sigma}\right)}{(\sigma+\theta)^2}\right] \tag{B.47}$$

Next, differentiating the compensated tax revenue function (B.45) with respect to taxable income, obtain

$$\frac{\partial T}{\partial \tilde{y}_m} = \frac{\partial T}{\partial \tilde{y}_f} = 1 - \lambda(1-\theta)\left(\tilde{y}_m + \tilde{y}_f\right)^{-\theta} = 1 - \lambda^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\left(\upsilon_m + \upsilon_f\right)^{-\frac{\sigma\theta}{\sigma+\theta}} \quad \text{(B.48)}$$

Using (B.46)-(B.47) and (B.48), I obtain the expression for marginal efficiency loss for (υ_m, υ_f)-couple under HSV tax and transfer function:

$$\frac{dD_{joint}\left(\upsilon_m, \upsilon_f\right)}{d\theta} = -\left[\frac{\partial T}{\partial \tilde{y}_m} \cdot \frac{d\tilde{y}_m}{d\theta} + \frac{\partial T}{\partial \tilde{y}_f} \cdot \frac{d\tilde{y}_f}{d\theta}\right] = \left[1 - \lambda^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\left(\upsilon_m + \upsilon_f\right)^{-\frac{\sigma\theta}{\sigma+\theta}}\right] \times$$
$$\frac{\left[\lambda(1-\theta)^{1-\sigma-\theta}\left(\upsilon_m + \upsilon_f\right)^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma+\theta}\left[1 + \frac{(1-\theta)\log\left(\lambda(1-\theta)\left(\upsilon_m + \upsilon_f\right)^{\sigma}\right)}{\sigma+\theta}\right] \quad \text{(B.49)}$$

Now I turn to the linearized program. Given the values of parameters $(\theta, \lambda, \sigma, \upsilon_m, \upsilon_f)$, denote the solution to the couple's problem by $\left(c^*, y_m^*, y_f^*\right)$. Linearizing the budget constraint (B.39) around this point, I obtain

$$c = \lambda(1-\theta)\left(y_m^* + y_f^*\right)^{-\theta}\left(y_m + y_f\right) + T^* \quad \text{(B.50)}$$

where $T^* = \lambda\theta\left(y_m^* + y_f^*\right)^{1-\theta} + c^*$.

Next, I plug the linearized budget constraint (B.50) into the objective function (B.38) and obtain the following first-order conditions:

$$\left(\frac{y_m}{\upsilon_m}\right)^{\sigma} = \lambda(1-\theta)\left(y_m^* + y_f^*\right)^{-\theta} \quad \text{(B.51)}$$

$$\left(\frac{y_f}{\upsilon_f}\right)^{\sigma} = \lambda(1-\theta)\left(y_m^* + y_f^*\right)^{-\theta} \quad \text{(B.52)}$$

Optimal taxable incomes in the problem with a linearized budget constraint are given by

$$\tilde{y}_m^L = \lambda^{\frac{1}{\sigma}}(1-\theta)^{\frac{1}{\sigma}}\left(y_m^* + y_f^*\right)^{-\frac{\theta}{\sigma}}\upsilon_m \quad \text{(B.53)}$$

$$\tilde{y}_f^L = \lambda^{\frac{1}{\sigma}}(1-\theta)^{\frac{1}{\sigma}}\left(y_m^* + y_f^*\right)^{-\frac{\theta}{\sigma}}\upsilon_f \quad \text{(B.54)}$$

Differentiating the compensated taxable income functions $\tilde{y}_m^L$ and $\tilde{y}_f^L$ with respect to the tax progressivity parameter θ, I obtain

$$\frac{d\tilde{y}_m^L}{d\theta} = -\left[\lambda(1-\theta)^{1-\sigma}\left(y_m^* + y_f^*\right)^{-\theta}\right]^{\frac{1}{\sigma}}\left[\frac{1}{\sigma} + \frac{(1-\theta)\log\left(y_m^* + y_f^*\right)}{\sigma}\right]\upsilon_m \tag{B.55}$$

$$\frac{d\tilde{y}_f^L}{d\theta} = -\left[\lambda(1-\theta)^{1-\sigma}\left(y_m^* + y_f^*\right)^{-\theta}\right]^{\frac{1}{\sigma}}\left[\frac{1}{\sigma} + \frac{(1-\theta)\log\left(y_m^* + y_f^*\right)}{\sigma}\right]\upsilon_f \tag{B.56}$$

Plugging the optimal taxable income, (B.53) and (B.54), into these expressions, I obtain

$$\frac{d\tilde{y}_m^L}{d\theta} = -\upsilon_m\left[\frac{\lambda(1-\theta)^{1-\sigma-\theta}}{(\upsilon_m+\upsilon_f)^{\theta}}\right]^{\frac{1}{\sigma+\theta}}\left[\frac{1}{\sigma} + \frac{(1-\theta)\log\left(\lambda(1-\theta)\left(\upsilon_m+\upsilon_f\right)^{\sigma}\right)}{\sigma(\sigma+\theta)}\right] \tag{B.57}$$

$$\frac{d\tilde{y}_f^L}{d\theta} = -\upsilon_f\left[\frac{\lambda(1-\theta)^{1-\sigma-\theta}}{(\upsilon_m+\upsilon_f)^{\theta}}\right]^{\frac{1}{\sigma+\theta}}\left[\frac{1}{\sigma} + \frac{(1-\theta)\log\left(\lambda(1-\theta)\left(\upsilon_m+\upsilon_f\right)^{\sigma}\right)}{\sigma(\sigma+\theta)}\right] \tag{B.58}$$

By construction, optimal taxable income in the problems with nonlinear and linearized tax functions coincide, i.e. $\tilde{y}_m = \tilde{y}_m^L$ and $\tilde{y}_f = \tilde{y}_f^L$. Therefore, $\partial T/\partial\tilde{y}_m = \partial T/\partial\tilde{y}_m^L$ and $\partial T/\partial\tilde{y}_f = \partial T/\partial\tilde{y}_f^L$. Using (B.48) and (B.57)-(B.58), I obtain marginal deadweight loss for (υ_m, υ_f)-couple in the problem with a linearized HSV tax function:

$$\frac{dD_{joint}^L(\upsilon_m,\upsilon_f)}{d\theta} = -\left[\frac{\partial T}{\partial\tilde{y}_m^L}\cdot\frac{d\tilde{y}_m^L}{d\theta} + \frac{\partial T}{\partial\tilde{y}_f^L}\cdot\frac{d\tilde{y}_f^L}{d\theta}\right] = \left[1 - \lambda^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\left(\upsilon_m+\upsilon_f\right)^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\times$$
$$\frac{\left[\lambda(1-\theta)^{1-\sigma-\theta}\left(\upsilon_m+\upsilon_f\right)^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma}\left[1 + \frac{(1-\theta)\log\left(\lambda(1-\theta)\left(\upsilon_m+\upsilon_f\right)^{\sigma}\right)}{\sigma+\theta}\right] \tag{B.59}$$

Finally, using the government budget constraint, I solve for λ as a function of policy parameters (θ, g) and primitives of the economy. The government budget constraint under joint taxation of spouses is given by

$$g\int\left(y_m+y_f\right)d\Gamma\left(\upsilon_m,\upsilon_f\right) = \int\left(y_m+y_f\right)d\Gamma\left(\upsilon_m,\upsilon_f\right) - \lambda\int\left(y_m+y_f\right)^{1-\theta}d\Gamma\left(\upsilon_m,\upsilon_f\right) \tag{B.60}$$

Solving for λ, I obtain

$$\lambda = \frac{(1-g)\int (y_m + y_f)\, d\Gamma(\upsilon_m, \upsilon_f)}{\int (y_m + y_f)^{1-\theta}\, d\Gamma(\upsilon_m, \upsilon_f)} \tag{B.61}$$

Finally, plugging (B.42) and (B.43), I derive the expression for the equilibrium value of λ under joint taxation of spouses:

$$\lambda = (1-g)^{\frac{\sigma+\theta}{\sigma}} (1-\theta)^{\frac{\theta}{\sigma}} \left[\frac{\int (\upsilon_m + \upsilon_f)^{\frac{\sigma}{\sigma+\theta}}\, d\Gamma(\upsilon_m, \upsilon_f)}{\int (\upsilon_m + \upsilon_f)^{\frac{\sigma(1-\theta)}{\sigma+\theta}}\, d\Gamma(\upsilon_m, \upsilon_f)} \right]^{\frac{\sigma+\theta}{\sigma}} \tag{B.62}$$

Note that, by construction, $\tilde{y}_m = \tilde{y}_m^L$ and $\tilde{y}_f = \tilde{y}_f^L$, and hence the values of λ in the original and linearized programs coincide. This completes the derivation of the expressions for reform-induced efficiency loss in the case of joint taxation of spousal incomes.

Separate Taxation of Spouses

The problem of couple characterized by preference parameters (υ_m, υ_f) is given by

$$\max_{c, y_m, y_f} c - \frac{\upsilon_m}{\sigma+1}\left(\frac{y_m}{\upsilon_m}\right)^{\sigma+1} - \frac{\upsilon_f}{\sigma+1}\left(\frac{y_f}{\upsilon_f}\right)^{\sigma+1} \tag{B.63}$$

$$\text{s.t.} \quad c = \tilde{\lambda} y_m^{1-\theta} + \tilde{\lambda} y_f^{1-\theta} \tag{B.64}$$

Substituting (B.64) into (B.63) and maximizing with respect to y_m and y_f, I obtain the following first-order conditions:

$$\left(\frac{y_m}{\upsilon_m}\right)^{\sigma} = \tilde{\lambda}(1-\theta) y_m^{-\theta} \tag{B.65}$$

$$\left(\frac{y_f}{\upsilon_f}\right)^{\sigma} = \tilde{\lambda}(1-\theta) y_f^{-\theta} \tag{B.66}$$

Then, using $y_m/y_f = (\upsilon_m/\upsilon_f)^{\frac{\sigma}{\sigma+\theta}}$, I derive the expressions for the optimal taxable income:

$$\tilde{y}_m = \tilde{\lambda}^{\frac{1}{\sigma+\theta}}(1-\theta)^{\frac{1}{\sigma+\theta}}\upsilon_m^{\frac{\sigma}{\sigma+\theta}} \tag{B.67}$$

$$\tilde{y}_f = \tilde{\lambda}^{\frac{1}{\sigma+\theta}}(1-\theta)^{\frac{1}{\sigma+\theta}}\upsilon_f^{\frac{\sigma}{\sigma+\theta}} \tag{B.68}$$

Substituting these expressions into (B.64), obtain the optimal consumption:

$$\tilde{c} = \tilde{\lambda}^{\frac{\sigma+1}{\sigma+\theta}}(1-\theta)^{\frac{1-\theta}{\sigma+\theta}}\left[\upsilon_m^{\frac{\sigma(1-\theta)}{\sigma+\theta}} + \upsilon_f^{\frac{\sigma(1-\theta)}{\sigma+\theta}}\right] \tag{B.69}$$

Given the quasilinear preferences, the income effect on taxable incomes is zero, and hence the Marshallian and Hicksian functions coincide. Next, using (B.67) and (B.68), I obtain

$$\begin{aligned} T(\tilde{y}_m, \tilde{y}_f, \theta) &= \tilde{y}_m + \tilde{y}_f - \tilde{\lambda}\tilde{y}_m^{1-\theta} - \tilde{\lambda}\tilde{y}_f^{1-\theta} = \\ &\tilde{\lambda}^{\frac{1}{\sigma+\theta}}(1-\theta)^{\frac{1}{\sigma+\theta}}\left[\upsilon_m^{\frac{\sigma}{\sigma+\theta}} + \upsilon_f^{\frac{\sigma}{\sigma+\theta}}\right] - \tilde{\lambda}^{\frac{\sigma+1}{\sigma+\theta}}(1-\theta)^{\frac{1-\theta}{\sigma+\theta}}\left[\upsilon_m^{\frac{\sigma(1-\theta)}{\sigma+\theta}} + \upsilon_f^{\frac{\sigma(1-\theta)}{\sigma+\theta}}\right] \end{aligned} \tag{B.70}$$

Differentiating the compensated taxable income functions $\tilde{y}_m$ and $\tilde{y}_f$ by parameter θ, I obtain

$$\frac{d\tilde{y}_m}{d\theta} = -\left[\tilde{\lambda}(1-\theta)\upsilon_m^{\sigma}\right]^{\frac{1}{\sigma+\theta}}\left[\frac{1}{(1-\theta)(\sigma+\theta)} + \frac{\log\left(\tilde{\lambda}(1-\theta)\upsilon_m^{\sigma}\right)}{(\sigma+\theta)^2}\right] \tag{B.71}$$

$$\frac{d\tilde{y}_f}{d\theta} = -\left[\tilde{\lambda}(1-\theta)\upsilon_f^{\sigma}\right]^{\frac{1}{\sigma+\theta}}\left[\frac{1}{(1-\theta)(\sigma+\theta)} + \frac{\log\left(\tilde{\lambda}(1-\theta)\upsilon_f^{\sigma}\right)}{(\sigma+\theta)^2}\right] \tag{B.72}$$

Next, differentiating the compensated tax revenue function (B.70) by taxable income,

$$\frac{\partial T}{\partial \tilde{y}_m} = 1 - \tilde{\lambda}(1-\theta)\tilde{y}_m^{-\theta} = 1 - \tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_m^{-\frac{\sigma\theta}{\sigma+\theta}} \tag{B.73}$$

$$\frac{\partial T}{\partial \tilde{y}_f} = 1 - \tilde{\lambda}(1-\theta)\tilde{y}_f^{-\theta} = 1 - \tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_f^{-\frac{\sigma\theta}{\sigma+\theta}} \tag{B.74}$$

Using (B.71)-(B.72) and (B.73)-(B.74), I obtain the expression for marginal efficiency loss for (υ_m, υ_f)-couple under HSV tax and transfer function:

$$\frac{dD_{sep}(\upsilon_m,\upsilon_f)}{d\theta} = -\left[\frac{\partial T}{\partial \tilde{y}_m}\cdot\frac{d\tilde{y}_m}{d\theta} + \frac{\partial T}{\partial \tilde{y}_f}\cdot\frac{d\tilde{y}_f}{d\theta}\right] =$$
$$\left[1-\tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_m^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\frac{\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_m^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma+\theta}\left[1+\frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_m^{\sigma}\right)}{\sigma+\theta}\right]+$$
$$\left[1-\tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_f^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\frac{\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_f^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma+\theta}\left[1+\frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_f^{\sigma}\right)}{\sigma+\theta}\right] \tag{B.75}$$

Now I turn to the linearized program. Given the values of parameters $\left(\theta,\tilde{\lambda},\sigma,\upsilon_m,\upsilon_f\right)$, denote the solution to the couple's problem by $\left(c^*, y_m^*, y_f^*\right)$. Linearizing the budget constraint (B.64) around this point, I obtain

$$c = \tilde{\lambda}(1-\theta)\left(y_m^*\right)^{-\theta} y_m + \tilde{\lambda}(1-\theta)\left(y_f^*\right)^{-\theta} y_f + T^* \tag{B.76}$$

where $T^* = \tilde{\lambda}\theta\left(y_m^*\right)^{1-\theta} + \tilde{\lambda}\theta\left(y_f^*\right)^{1-\theta} + c^*$.

Next, I plug the linearized budget constraint (B.76) into the objective function (B.63) and obtain the following first-order conditions:

$$\left(\frac{y_m}{\upsilon_m}\right)^{\sigma} = \tilde{\lambda}(1-\theta)\left(y_m^*\right)^{-\theta} \tag{B.77}$$

$$\left(\frac{y_f}{\upsilon_f}\right)^{\sigma} = \tilde{\lambda}(1-\theta)\left(y_f^*\right)^{-\theta} \tag{B.78}$$

Optimal taxable incomes in the problem with a linearized budget constraint are given by

$$\tilde{y}_m^L = \tilde{\lambda}^{\frac{1}{\sigma}}(1-\theta)^{\frac{1}{\sigma}}\left(y_m^*\right)^{-\frac{\theta}{\sigma}}\upsilon_m \tag{B.79}$$

$$\tilde{y}_f^L = \tilde{\lambda}^{\frac{1}{\sigma}}(1-\theta)^{\frac{1}{\sigma}}\left(y_f^*\right)^{-\frac{\theta}{\sigma}}\upsilon_f \tag{B.80}$$

Differentiating the compensated taxable income functions $\tilde{y}_m^L$ and $\tilde{y}_f^L$ with respect to the tax progressivity parameter θ, I obtain

$$\frac{d\tilde{y}_m^L}{d\theta} = -\left[\tilde{\lambda}(1-\theta)^{1-\sigma}\left(y_m^*\right)^{-\theta}\right]^{\frac{1}{\sigma}}\left[\frac{1}{\sigma} + \frac{(1-\theta)\log y_m^*}{\sigma}\right]\upsilon_m \tag{B.81}$$

$$\frac{d\tilde{y}_f^L}{d\theta} = -\left[\tilde{\lambda}(1-\theta)^{1-\sigma}\left(y_f^*\right)^{-\theta}\right]^{\frac{1}{\sigma}}\left[\frac{1}{\sigma} + \frac{(1-\theta)\log y_f^*}{\sigma}\right]\upsilon_f \tag{B.82}$$

Plugging the optimal taxable income, (B.67) and (B.68), into these expressions, I get

$$\frac{\partial\tilde{y}_m^L}{\partial\theta} = -\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_m^{\sigma}\right]^{\frac{1}{\sigma+\theta}}\left[\frac{1}{\sigma} + \frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_m^{\sigma}\right)}{\sigma(\sigma+\theta)}\right] \tag{B.83}$$

$$\frac{\partial\tilde{y}_f^L}{\partial\theta} = -\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_f^{\sigma}\right]^{\frac{1}{\sigma+\theta}}\left[\frac{1}{\sigma} + \frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_f^{\sigma}\right)}{\sigma(\sigma+\theta)}\right] \tag{B.84}$$

By construction, optimal taxable income in the problems with nonlinear and linearized tax functions coincide, i.e. $\tilde{y}_m = \tilde{y}_m^L$ and $\tilde{y}_f = \tilde{y}_f^L$. Therefore, $\partial T/\partial\tilde{y}_m = \partial T/\partial\tilde{y}_m^L$ and $\partial T/\partial\tilde{y}_f = \partial T/\partial\tilde{y}_f^L$. Using (B.73)-(B.74) and (B.83)-(B.84), I obtain marginal deadweight loss for (υ_m, υ_f)-couple in the problem with a linearized HSV tax function:

$$\frac{dD_{sep}^L(\upsilon_m,\upsilon_f)}{d\theta} = -\left[\frac{\partial T}{\partial\tilde{y}_m^L}\cdot\frac{d\tilde{y}_m^L}{d\theta} + \frac{\partial T}{\partial\tilde{y}_f^L}\cdot\frac{d\tilde{y}_f^L}{d\theta}\right] =$$
$$\left[1-\tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_m^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\frac{\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_m^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma}\left[1+\frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_m^{\sigma}\right)}{\sigma+\theta}\right]+$$
$$\left[1-\tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_f^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\frac{\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_f^{\sigma}\right]^{\frac{1}{\sigma+\theta}}}{\sigma}\left[1+\frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_f^{\sigma}\right)}{\sigma+\theta}\right] \tag{B.85}$$

Finally, using the government budget constraint, I solve for $\tilde{\lambda}$ as a function of policy parameters (θ, g) and primitives of the economy. The government budget constraint under separate taxation of spousal incomes takes the following form:

$$g\int(y_m+y_f)\,d\Gamma(\upsilon_m,\upsilon_f)=\int(y_m+y_f)\,d\Gamma(\upsilon_m,\upsilon_f)-\tilde{\lambda}\int\left(y_m^{1-\theta}+y_f^{1-\theta}\right)d\Gamma(\upsilon_m,\upsilon_f) \tag{B.86}$$

Solving for $\tilde{\lambda}$, I obtain

$$\tilde{\lambda}=\frac{(1-g)\int(y_m+y_f)\,d\Gamma(\upsilon_m,\upsilon_f)}{\int\left(y_m^{1-\theta}+y_f^{1-\theta}\right)d\Gamma(\upsilon_m,\upsilon_f)} \tag{B.87}$$

Finally, plugging (B.67) and (B.68), I get the expression for the equilibrium value of $\tilde{\lambda}$ under separate taxation of spouses:

$$\tilde{\lambda}=(1-g)^{\frac{\sigma+\theta}{\sigma}}(1-\theta)^{\frac{\theta}{\sigma}}\left[\frac{\int\left(\upsilon_m^{\frac{\sigma}{\sigma+\theta}}+\upsilon_f^{\frac{\sigma}{\sigma+\theta}}\right)d\Gamma(\upsilon_m,\upsilon_f)}{\int\left(\upsilon_m^{\frac{\sigma(1-\theta)}{\sigma+\theta}}+\upsilon_f^{\frac{\sigma(1-\theta)}{\sigma+\theta}}\right)d\Gamma(\upsilon_m,\upsilon_f)}\right]^{\frac{\sigma+\theta}{\sigma}} \tag{B.88}$$

Note that, by construction, $\tilde{y}_m=\tilde{y}_m^L$ and $\tilde{y}_f=\tilde{y}_f^L$, and hence the values of $\tilde{\lambda}$ in the original and linearized programs coincide. This completes the derivation of the expressions for reform-induced efficiency loss in the case of separate taxation of spousal incomes.

Overall, this completes the proof of Proposition B.1. ■

B.1.4 Proof of Proposition 2.3

Joint Taxation of Spouses

By definition, the linearization bias is given by

$$\Delta_{joint} = \frac{\frac{dD^L_{joint}}{d\theta} - \frac{dD_{joint}}{d\theta}}{\frac{dD_{joint}}{d\theta}} = \frac{\int \frac{dD^L_{joint}(\upsilon_m,\upsilon_f)}{d\theta} d\Gamma(\upsilon_m,\upsilon_f) - \int \frac{dD_{joint}(\upsilon_m,\upsilon_f)}{d\theta} d\Gamma(\upsilon_m,\upsilon_f)}{\int \frac{dD_{joint}(\upsilon_m,\upsilon_f)}{d\theta} d\Gamma(\upsilon_m,\upsilon_f)}$$

Plugging (B.49) and (B.59) from the first part of Proposition B.1, I obtain

$$\Delta_{joint} = \frac{\left(\frac{1}{\sigma}-\frac{1}{\sigma+\theta}\right)\int\left[1-\lambda^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\left(\upsilon_m+\upsilon_f\right)^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\left[\lambda(1-\theta)^{1-\sigma-\theta}\left(\upsilon_m+\upsilon_f\right)^{\sigma}\right]^{\frac{1}{\sigma+\theta}}\left[1+\frac{(1-\theta)\log\left(\lambda(1-\theta)\left(\upsilon_m+\upsilon_f\right)^{\sigma}\right)}{\sigma+\theta}\right]d\Gamma(\upsilon_m,\upsilon_f)}{\frac{1}{\sigma+\theta}\int\left[1-\lambda^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\left(\upsilon_m+\upsilon_f\right)^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\left[\lambda(1-\theta)^{1-\sigma-\theta}\left(\upsilon_m+\upsilon_f\right)^{\sigma}\right]^{\frac{1}{\sigma+\theta}}\left[1+\frac{(1-\theta)\log\left(\lambda(1-\theta)\left(\upsilon_m+\upsilon_f\right)^{\sigma}\right)}{\sigma+\theta}\right]d\Gamma(\upsilon_m,\upsilon_f)}$$

Finally, simplifying, I find that the linearization bias is given by the ratio between the tax progressivity parameter θ and the inverse elasticity of taxable income σ:

$$\Delta_{joint} = \frac{\frac{1}{\sigma} - \frac{1}{\sigma+\theta}}{\frac{1}{\sigma+\theta}} = \frac{\theta}{\sigma} \tag{B.89}$$

Separate Taxation of Spouses

The linearization bias is given by

$$\Delta_{sep} = \frac{\frac{dD^L_{sep}}{d\theta} - \frac{dD_{sep}}{d\theta}}{\frac{dD_{sep}}{d\theta}} = \frac{\int \frac{dD^L_{sep}(\upsilon_m,\upsilon_f)}{d\theta} d\Gamma(\upsilon_m,\upsilon_f) - \int \frac{dD_{sep}(\upsilon_m,\upsilon_f)}{d\theta} d\Gamma(\upsilon_m,\upsilon_f)}{\int \frac{dD_{sep}(\upsilon_m,\upsilon_f)}{d\theta} d\Gamma(\upsilon_m,\upsilon_f)}$$

Plugging (B.75) and (B.85) from the second part of Proposition B.1, I obtain

$$\Delta_{sep} = \frac{\left(\frac{1}{\sigma}-\frac{1}{\sigma+\theta}\right)\int\sum_{j=m,f}\left[1-\tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_j^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_j^{\sigma}\right]^{\frac{1}{\sigma+\theta}}\left[1+\frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_j^{\sigma}\right)}{\sigma+\theta}\right]d\Gamma(\upsilon_m,\upsilon_f)}{\frac{1}{\sigma+\theta}\int\sum_{j=m,f}\left[1-\tilde{\lambda}^{\frac{\sigma}{\sigma+\theta}}(1-\theta)^{\frac{\sigma}{\sigma+\theta}}\upsilon_j^{-\frac{\sigma\theta}{\sigma+\theta}}\right]\left[\tilde{\lambda}(1-\theta)^{1-\sigma-\theta}\upsilon_j^{\sigma}\right]^{\frac{1}{\sigma+\theta}}\left[1+\frac{(1-\theta)\log\left(\tilde{\lambda}(1-\theta)\upsilon_j^{\sigma}\right)}{\sigma+\theta}\right]d\Gamma(\upsilon_m,\upsilon_f)}$$

Finally, simplifying, I find that the linearization bias coincides with one I obtain under joint taxation of couples:

$$\Delta_{sep} = \frac{\frac{1}{\sigma} - \frac{1}{\sigma+\theta}}{\frac{1}{\sigma+\theta}} = \frac{\theta}{\sigma} \tag{B.90}$$

This completes the proof of Proposition 2.3. ■

B.2 Additional Figures

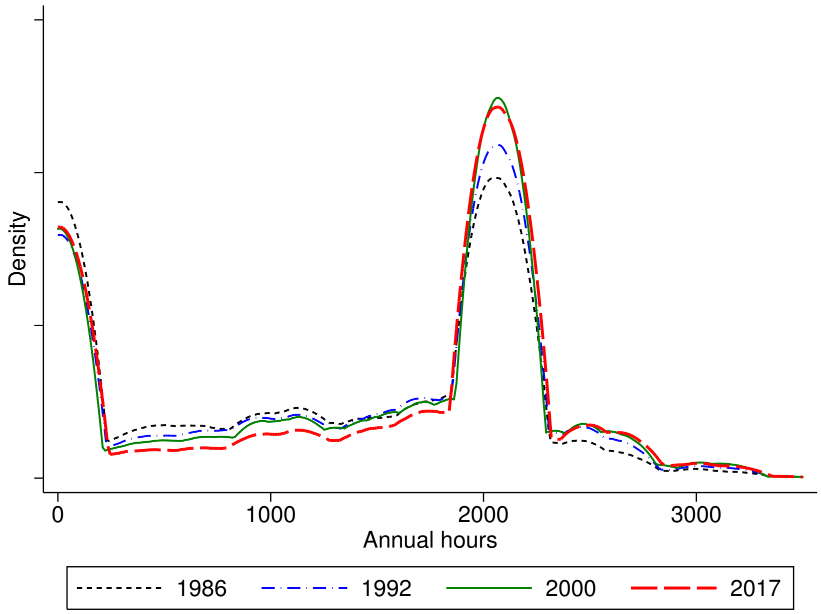
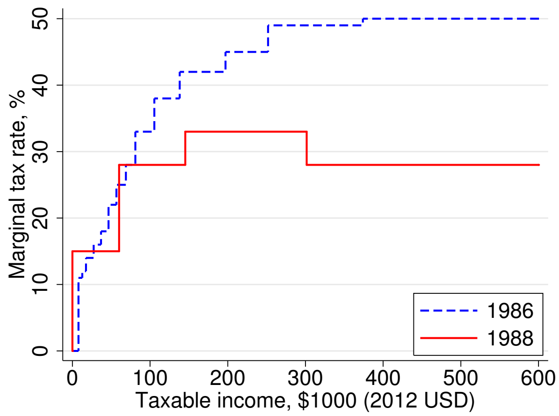
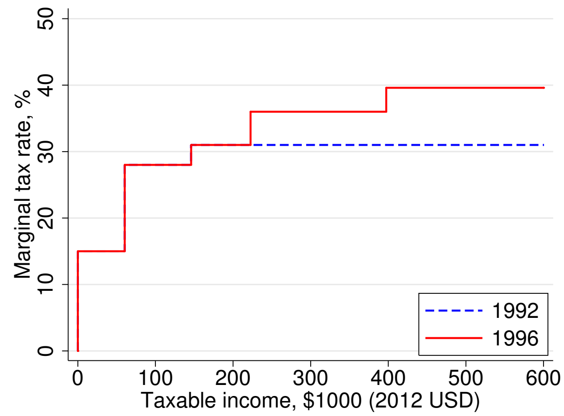


Figure B.1: Annual Working Hours of Married Women with Employed Husbands in the United States

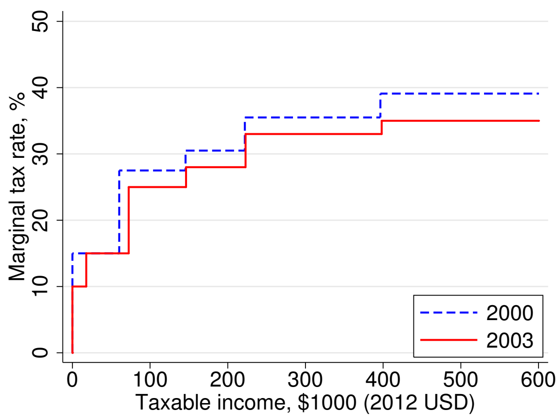
NOTES: Data is from the Annual Social and Economic Supplement of the Current Population Survey. The sample includes married women aged 25-54 with working husbands.



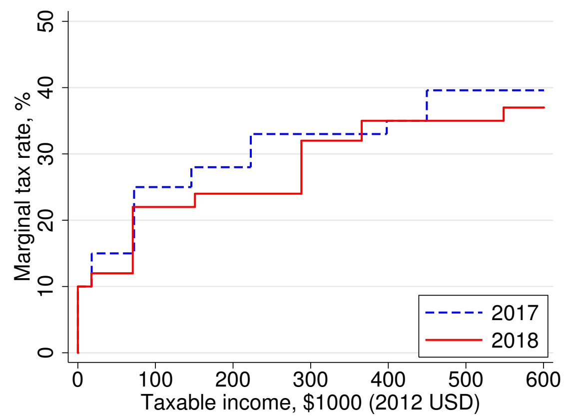
(a) TRA 1986 reform



(b) OBRA 1993 reform



(c) EGTRRA 2001 reform



(d) TCJA 2017 reform

Figure B.2: Pre-Reform and Post-Reform U.S. Federal Income Tax Brackets and Statutory Marginal Tax Rates for Married Couples Filing Jointly

B.3 Additional Tables

Table B.1: Summary Statistics, 1986 and 1992

	1986			1992		
	Mean	Median	St. Dev.	Mean	Median	St. Dev.
Males						
Age	38.94	38	7.88	39.48	39	7.61
White	0.896	1	0.305	0.892	1	0.311
College degree	0.291	0	0.454	0.311	0	0.463
Annual hours	2201	2080	588	2217	2080	606
Earnings (2012 USD)	52873	47893	30218	53919	47610	33521
Females						
Age	36.66	36	7.55	37.47	37	7.37
White	0.895	1	0.306	0.891	1	0.312
College degree	0.211	0	0.408	0.259	0	0.438
Employment	0.732	1	0.443	0.764	1	0.425
Annual hours	1214	1400	940	1330	1664	939
Earnings (2012 USD)	25946	22104	19507	29740	25293	21906
Number of children	1.62	2	1.22	1.54	2	1.19
Number of children under 6	0.50	0	0.78	0.49	0	0.77
Female — secondary earner	0.834	1	0.372	0.788	1	0.409
Number of observations		17127			18032	

NOTES: Data is from the Annual Social and Economic Supplement of the Current Population Survey. The sample includes married couples aged 25-54 with working husbands. Secondary earner is defined as the person with the lowest income among two spouses. Details about sample selection are given in the main text. To calculate the summary statistics, I use the CPS ASEC weights.

Table B.2: Summary Statistics, 2000 and 2017

	2000			2017		
	Mean	Median	St. Dev.	Mean	Median	St. Dev.
Males						
Age	40.63	41	7.63	40.76	41	7.77
White	0.865	1	0.341	0.812	1	0.391
College degree	0.351	0	0.477	0.440	0	0.496
Annual hours	2294	2080	558	2229	2080	532
Earnings (2012 USD)	72918	53688	74811	76318	56644	81251
Females						
Age	38.78	39	7.57	38.96	39	7.78
White	0.862	1	0.345	0.804	1	0.397
College degree	0.324	0	0.468	0.493	0	0.500
Employment rate	0.777	1	0.416	0.747	1	0.435
Annual hours	1393	1820	947	1388	1872	971
Earnings (2012 USD)	37659	31332	37063	49817	37763	54504
Number of children	1.55	2	1.23	1.61	2	1.27
Number of children under 6	0.46	0	0.76	0.51	0	0.79
Female — secondary earner	0.775	1	0.417	0.720	1	0.449
Number of observations		26883			17415	

NOTES: Data is from the Annual Social and Economic Supplement of the Current Population Survey. The sample includes married couples aged 25-54 with working husbands. Secondary earner is defined as the person with the lowest income among two spouses. Details about sample selection are given in the main text. To calculate the summary statistics, I use the CPS ASEC weights.

Table B.3: EITC Parameters for U.S. Married Couples Filing Jointly, 1986-2018

Year	Eligible Children	Phase-In Rate, %	First Kink, $	Maximum Credit, $	Second Kink, $	Phase-Out Rate, %	Exhaustion Point, $
1986	any	11	5000	550	6500	12.22	11000
1987	any	14	6080	851	6920	10	15432
1988	any	14	6240	874	9840	10	18576
1989	any	14	6500	910	10240	10	19340
1990	any	14	6810	953	10730	10	20264
1991	1	16.7	7140	1192	11250	11.93	21250
	2+	17.3	7140	1235	11250	12.36	21250
1992	1	17.6	7520	1324	11840	12.57	22370
	2+	18.4	7520	1384	11840	13.14	22370
1993	1	18.5	7750	1434	12200	13.21	23050
	2+	19.5	7750	1511	12200	13.93	23050
1994	0	7.65	4000	306	5000	7.65	9000
	1	26.3	7750	2038	11000	15.98	23755
	2+	30	8425	2528	11000	17.68	25296
1995	0	7.65	4100	314	5130	7.65	9230
	1	34	6160	2094	11290	15.98	24396
	2+	36	8640	3110	11290	20.22	26673
1996	0	7.65	4220	323	5280	7.65	9500
	1	34	6330	2152	11610	15.98	25078
	2+	40	8890	3556	11610	21.06	28495
1997	0	7.65	4340	332	5430	7.65	9770
	1	34	6500	2210	11930	15.98	25750
	2+	40	9140	3656	11930	21.06	29290
1998	0	7.65	4460	341	5570	7.65	10030
	1	34	6680	2271	12260	15.98	26473
	2+	40	9390	3756	12260	21.06	30095
1999	0	7.65	4530	347	5670	7.65	10200
	1	34	6800	2312	12460	15.98	26928
	2+	40	9540	3816	12460	21.06	30580
2000	0	7.65	4610	353	5770	7.65	10380
	1	34	6920	2353	12690	15.98	27413
	2+	40	9720	3888	12690	21.06	31152
2001	0	7.65	4760	364	5950	7.65	10710
	1	34	7140	2428	13090	15.98	28281
	2+	40	10020	4008	13090	21.06	32121
2002	0	7.65	4910	376	7150	7.65	12060
	1	34	7370	2506	14520	15.98	30201
	2+	40	10350	4140	14520	21.06	34178

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Table B.3 – continued from previous page

Year	Eligible Children	Phase-In Rate, %	First Kink, $	Maximum Credit, $	Second Kink, $	Phase-Out Rate, %	Exhaustion Point, $
2003	0	7.65	4990	382	7240	7.65	12230
	1	34	7490	2547	14730	15.98	30666
	2+	40	10510	4204	14730	21.06	34692
2004	0	7.65	5100	390	7390	7.65	12490
	1	34	7660	2604	15040	15.98	31338
	2+	40	10750	4300	15040	21.06	35458
2005	0	7.65	5220	399	8530	7.65	13750
	1	34	7830	2662	16370	15.98	33030
	2+	40	11000	4400	16370	21.06	37263
2006	0	7.65	5380	412	8740	7.65	14120
	1	34	8080	2747	16810	15.98	34001
	2+	40	11340	4536	16810	21.06	38348
2007	0	7.65	5590	428	9000	7.65	14590
	1	34	8390	2853	17390	15.98	35241
	2+	40	11790	4716	17390	21.06	39783
2008	0	7.65	5720	438	10160	7.65	15880
	1	34	8580	2917	18740	15.98	36995
	2+	40	12060	4824	18740	21.06	41646
2009	0	7.65	5970	457	12470	7.65	18440
	1	34	8950	3043	21420	15.98	40463
	2	40	12570	5028	21420	21.06	45295
	3+	45	12570	5657	21420	21.06	48279
2010	0	7.65	5980	457	12490	7.65	18470
	1	34	8970	3050	21460	15.98	40545
	2	40	12590	5036	21460	21.06	45373
	3+	45	12590	5666	21460	21.06	48362
2011	0	7.65	6070	464	12670	7.65	15740
	1	34	9100	3094	21770	15.98	41132
	2	40	12780	5112	21770	21.06	46044
	3+	45	12780	5751	21770	21.06	49078
2012	0	7.65	6210	475	12980	7.65	19190
	1	34	9320	3169	22300	15.98	42130
	2	40	13090	5236	22300	21.06	47162
	3+	45	13090	5891	22300	21.06	50270
2013	0	7.65	6370	487	13310	7.65	19680
	1	34	9560	3250	22870	15.98	43210
	2	40	13430	5372	22870	21.06	48378
	3+	45	13430	6044	22870	21.06	51567

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Table B.3 – continued from previous page

Year	Eligible Children	Phase-In Rate, %	First Kink, $	Maximum Credit, $	Second Kink, $	Phase-Out Rate, %	Exhaustion Point, $
2014	0	7.65	6480	496	13540	7.65	20020
	1	34	9720	3305	23260	15.98	43941
	2	40	13650	5460	23260	21.06	49186
	3+	45	13650	6143	23260	21.06	52427
2015	0	7.65	6580	503	13760	7.65	20340
	1	34	9880	3359	23630	15.98	44651
	2	40	13870	5548	23630	21.06	49974
	3+	45	13870	6242	23630	21.06	53267
2016	0	7.65	6610	506	13820	7.65	20430
	1	34	9920	3373	23740	15.98	44846
	2	40	13931	5572	23740	21.06	50198
	3+	45	13930	6269	23740	21.06	53505
2017	0	7.65	6670	510	13930	7.65	20600
	1	34	10000	3400	23930	15.98	45207
	2	40	14040	5616	23930	21.06	50597
	3+	45	14040	6318	23930	21.06	53930
2018	0	7.65	6780	519	14170	7.65	20950
	1	34	10180	3461	24350	15.98	46010
	2	40	14290	5716	24350	21.06	51492
	3+	45	14290	6431	24350	21.06	54884

NOTES: This table shows the federal Earned Income Tax Credit parameters by family size for married couples filing jointly. Eligible children are under age 19 (under 24 if a full-time student) or permanently disabled and must reside with the taxpayer for more than half a year. Since 2002, the values of the second kink and exhaustion point were increased for married taxpayers filing jointly relative to taxpayers filing as single or the head of household. The phase-in rate is defined as the increase in the tax credit for an additional dollar of income. The first kink point corresponds to minimum income that is needed for maximizing the size of tax credit. The second kink point corresponds to maximum income allowed before the phasing-out region. The phase-out rate is defined as the reduction in the tax credit for an additional dollar of income above the second kink point. The exhaustion point corresponds to income at which the Earned Income Tax Credit is completely phased out.

Table B.4: Standard Deductions and Personal Exemptions for U.S. Married Couples Filing Jointly

Year	Standard Deduction	Personal Exemption
1986	3670	1080
1987	3760	1900
1988	5000	1950
1989	5200	2000
1990	5450	2050
1991	5700	2150
1992	6000	2300
1993	6200	2350
1994	6350	2450
1995	6550	2500
1996	6700	2550
1997	6900	2650
1998	7100	2700
1999	7200	2750
2000	7350	2800
2001	7600	2900
2002	7850	3000
2003	9500	3050
2004	9700	3100
2005	10000	3200
2006	10300	3300
2007	10700	3400
2008	10900	3500
2009	11400	3650
2010	11400	3650
2011	11600	3700
2012	11900	3800
2013	12200	3900
2014	12400	3950
2015	12600	4000
2016	12600	4050
2017	12700	4050
2018	24000	0

NOTES: The Tax Cuts and Jobs Act of 2017 eliminated personal exemptions for tax years 2018-2025.

B.4 NBER TAXSIM Inputs

To calculate the tax liabilities, the Internet NBER TAXSIM uses 32 input variables. As described in the text, I set most of them to zero because I do not model such things as childcare, capital income, housing, etc. Below I provide the full list of input variables with the details on each field.

1. *taxsimid*: Individual ID.
2. *year*: Tax year.
3. *state* = 23 (Michigan): State.
4. *mstat* = 2 (married filing jointly): Marital status.
5. *page*: Age of primary taxpayer.
6. *sage*: Age of spouse.
7. *depx* = 2: Number of dependents.
8. *dep13* = 2: Number of children under 13.
9. *dep17* = 2: Number of children under 17.
10. *dep18* = 2: Number of qualifying children for EITC.
11. *pwages*: Wage and salary income of primary taxpayer (including self-employment).
12. *swages*: Wage and salary income of spouse (including self-employment).
13. *dividends* = 0: Dividend income.
14. *intrec* = 0: Interest received.
15. *stcg* = 0: Short term capital gains or losses.
16. *ltcg* = 0: Long term capital gains or losses.
17. *otherprop* = 0: Other property income subject to Net Investment Income Tax (NIIT).

18. *nonprop* = 0: Other non-property income not subject to Medicare NIIT.

19. *pensions* = 0: Taxable pensions and IRA distributions.

20. *gssi* = 0: Gross Social Security benefits.

21. *ui* = 0: Unemployment compensation received.

22. *transfers* = 0: Other non-taxable transfer income.

23. *rentpaid* = 0: Rent paid.

24. *proptax* = 0: Real estate taxes paid.

25. *otheritem* = 0: Other itemized deductions that are a preference for the Alternative Minimum Tax (AMT).

26. *childcare* = 0: Child care expenses.

27. *mortgage* = 0: Deductions not included in *otheritem* and not a preference for the AMT.

28. *scorp* = 0: Active S-Corp income.

29. *pbusinc* = 0: Primary taxpayer's Qualified Business Income (QBI) subject to a preferential rate without phaseout.

30. *pprofinc* = 0: Primary taxpayer's Specialized Service Trade or Business service (SSTB) with a preferential rate subject to claw-back.

31. *sbusinc* = 0: Spouse's QBI.

32. *sprofinc* = 0: Spouse's SSTB.