Singles, Couples, Time-Averaging, and Taxation*

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Abstract: We study consequences of tax reforms in an incomplete markets overlapping generations model in which male and female workers with different ability levels self-insure by acquiring a risk-free bond, "time-averaging" their life-cycle work schedules and career lengths, and possibly by marrying and divorcing. We study incidences of a flat-rate tax, stylized versions of a negative income tax (NIT), an earned income tax credit (EITC), and combinations of them. Tax reforms have diverse effects that differ by workers' abilities, marital statuses, and ages. A new "*ex post-ex ante*" criterion helps us to sort through welfare incidences. The importance of labor supply responses at the extensive margin makes the EITC better for redistribution than the NIT.

Keywords: Precautionary Saving, Labor Supply, Time-Averaging, Social Security, Heterogeneous Households

JEL: E62, H20, H31, H53, H55, J21, J22, J26

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This is the point of 'microeconomic foundations' of macroeconomic models: to discover parameterizations that have interpretations in terms of specific aspects of preferences or of technology, so that the broadest range of evidence can be brought to bear on their magnitudes and their stability under various possible conditions.

Lucas (1987, p. 46)

1 Introduction

Lucas (1987, p. 47) praised Kydland & Prescott (1980) as a "model that actually makes contact with microeconomic studies in labor economics." But there are microfoundations and there are microfoundations, and prominent labor economists were dubious about the Rogerson (1988) employment lotteries and complete markets microfoundations that underlie the high aggregate labor supply elasticities in real business cycle models like Kydland & Prescott's as well as Prescott's (2002) analysis of Europe's high tax-and-spend regime and the original version of Prescott's Nobel lecture (Prescott (2005, p. 385)). Thus, Browning, Hansen & Heckman (1999, p. 602) wrote that Prescott's "employment allocation mechanism strains credibility and is at odds with the micro evidence on individual employment histories." Prescott abandoned those employment lotteries as microfoundations when he rewrote his Nobel lecture (Prescott 2006*b*).[1] Shortly before rewriting his Nobel lecture, Prescott (2006*a*, p. 233) recommended deriving "... implications of labor indivisibility for lifetime labor supply ..." and proceeded to advocate for incomplete markets, life-cycle models in which "what gets determined is the fraction of the periods of an individual's lifetime that an individual works and the fraction of the population working at each point in time."

Macroeconomists including Ríos-Rull (1996, 2008), for example, had already been using life-cycle models, but usually with exogenous retirement ages. When macroeconomists including Prescott began using life-cycle models that include time-averaging components in the form of indivisibilities in labor supply and endogenous career lengths, it brought us closer to realizing the vision in the epigraph from Lucas above. In this spirit, Graves, Gregory,

[1]Appendix A.1 provides an account of how Prescott's discussion (Prescott (2006*a*)) of Ljungqvist & Sargent (2006) served as a shock that convinced Prescott to find new microfoundations. Appendix A.1 describes how and why the time-averaging model has come to displace the Rogerson (1988) employment lottery model in many general equilibrium macro-labor models now used in macroeconomics. In a time-averaging model, every period a labor supply indivisibility confronts a finitely lived agent with a decision about whether to work or not to work. The worker saves and dissaves a risk-free bond in order to smooth his or her consumption over periods of working and not working. Model builders typically rig a time averaging model so that extended periods of not working occur at the ends of lives and are called "retirement", as we do here.

Ljungqvist & Sargent (2023) endogenized the hard-wired career lengths in Heckman, Lochner & Taber (1998) and analyzed time-averaging forces on career lengths that can be activated by tax rate changes that induce some agents to shorten their career. Among other findings, Graves et al. discovered that the Ben-Porath (1967) technology for human capital accumulation present in the Heckman et al. model activates the same experience-profile dependence of labor supply responses described in Ljungqvist & Sargent (2014). Since Heckman et al. estimate the human capital accumulation technology of college educated workers to be more productive than for high school educated workers, college workers are inclined to choose to accumulate more human capital and have longer careers than high school workers in a time-averaging version of Heckman et al.

This paper takes another step in the direction of uniting macro and micro economic analysis beneath a time-averaging umbrella. We add opportunities for time-averaging labor supplies over life cycles to an overlapping generations model of single, married, and divorced men and women of diverse abilities that Holter, Krueger & Stepanchuk (2019) (henceforth HKS) used to study quantitative consequences of alternative US fiscal policies.[2,3] Specifically, we add an extensive margin to men's labor supply and drop HKS's assumption of an exogenous retirement age.

The HKS model attracts us as a laboratory for studying welfare effects of social security and tax reforms because of how it includes interesting sources of heterogeneities across agents. At any point in time, agents differ by their ages, abilities, years of experience, productivity levels, marital status, and accumulated wealth levels. They also differ in terms of their prospects for changing their marital status, years of experience, wealth, and productivity. Social security arrangements and tax systems are bound to have indirect effects on distributions of labor earnings, private wealth, consumption, and welfare across agents that emerge from a general equilibrium that reconciles diverse agents' responses to their budget sets.[4]

[2]In Graves et al. (2023), we implemented time averaging in the model of Heckman et al. (1998), one of whose authors was dubious about the employment-lottery aggregation theory (see Browning, Hansen & Heckman (1999, p. 602), as cited above). Now we add opportunities for time-averaging labor supplies over life cycles to the model of HKS, one co-author of which was sympathetic to using employment lotteries as a microfoundation. Thus, Krueger (2007, sec. 9.2) presented an enlightening exposition of the virtues of an Rogerson (1988) employment-lottery aggregation theory. In this way, we aim to convince researchers on both sides of the earlier employment-lottery debate of the virtues of incorporating time averaging with endogenous career lengths.

[3]Chakraborty et al. (2015) and Holter et al. (2024) use a model similar to Holter et al. (2019) to answer questions about labor supply and taxation. Chakraborty et al. (2015) revisit an issue raised by Prescott (2004), namely, how much cross-country variation in hours worked can be explained by cross-country differences in tax rates. They estimate tax schedules for 18 countries and study their effects on intensive and extensive labor supply margins. Holter et al. (2024) study interactions between joint and individual taxation of married couples and tax progressivity and their effects on Laffer curves and social welfare.

[4]As agents age, being married or being single become more and more persistent states. We want to study

Our respect for how HKS calibrated their model to match US data induced us to take it as our starting point. Our approach is to retain as much of their structure and as many of their parameterizations as we can, then to investigate the quantitative consequences of modifying government social security and tax policies that affect agents' budget sets.[5]

We proceed by forming two "benchmark" models. Both benchmark models retain HKS's adoption of a labor income tax schedule borrowed from Benabou (2002), described and calibrated in sections 2 and 3. "Benchmark 1 model" is our time-averaging version of HKS combined with a social security system with benefit payout rules that induces many workers to choose to retire at age 65, the same maximum career length imposed in the HKS model. This social security system imposes an implicit tax on working beyond age 65 that creates a kink in budget sets that puts workers at corner solutions for career lengths at age 65. Parameterizations and calibrations that we use throughout this paper are done once and for all in benchmark 1 model. Benchmark 1 model is our reference point for quantitative comparisons that we use to study the mechanics of time-averaging in sections 4.2 and 4.3, in particular, by studying how agents with different abilities, genders, and marital situations choose career lengths in ways that are affected by the kinks in their budget sets put there by benchmark 1 model's social security system, and by exploring how effects of alternative tax schedules depend on how the government spends the tax revenues.

Starting in section 4.4 and proceeding through the remainder of the paper, we switch to using our second benchmark model as our reference point for quantitative comparisons. "Benchmark 2 model" is actually identical to benchmark 1 model except that a new social security system is installed, as described in section 4.4. Thus, benchmark 2 model retains all aspects of HKS's model specification that we imported into benchmark 1 model including its

how tax reforms affect lifetime welfare of individuals who end up single instead of being married. That motivated us to construct another welfare measure designed to address possible concerns about collections of agents who, because of their own personal life experiences, nevertheless find themselves in the same bad situation. Of course, because individuals would enter and leave that state for various reasons as time passes, the particular individuals who comprise such a collection would vary over time. To recognize that possibility, we propose a welfare measure that includes all agents who *ex post* find themselves in that state at a given age. We call this an *ex post-ex ante* welfare criterion. In section 4.5, we apply it to study the *ex ante* welfare of some agents conditional on their *ex post* being in a particular marital state at some future age.

[5]Proceeding in this way ties our hands in many ways, for example, by convincing us not to study the consequences of departing substantially from HKS's calibration of agents' earning shock process in ways discussed in appendix A.5. We also retain HKS's representation of a married couple as a unitary household that awards each spouse the same utility of consumption that a single person would have gathered from consuming everything that the couple consumes. We recognize that an alternative choice of household equivalence scale would quantitatively affect our welfare analysis. Nevertheless, because the tax schedule that along with HKS we have imported from Benabou (2002) helps married couples with low incomes, we believe that, so long as there are sufficient economies of scale in marriage, our main conclusions would be qualitatively similar under alternative household equivalence scales. Married individuals of the lowest abilities stand to lose most when we switch from the benchmark model's progressive tax schedule to one of our flat-rate tax reforms.

tax code except that it specifies a different social security system than the one in benchmark 1 model. In particular, benchmark 2 model instead has a social security system that is a stylized version of one that only recently went fully into effect in the US. This system removes the implicit tax on working after age 65 and the kinks that it put in agents' budget sets. We use benchmark 2 model as reference point in section 4.5 and throughout section 5.

Section 5 uses benchmark 2 model as a gauge against which we compare outcomes and welfare consequences of three types of reforms of the Benabou (2002) labor tax schedule. Section 5 analyzes several tax reforms whose effects are shaped by large aggregate and individual labor supply elasticities that come mainly from different career length responses at the extensive margin. This section studies a flat rate tax, a negative income tax (NIT), and an earned income tax credit (EITC), as well as "combined policies" that mix aspects of a flat rate tax with an NIT, on the one hand, and with an EITC, on the other hand. The salience of labor supply responses at extensive margins makes an EITC better than an NIT as an instrument for supporting people in less advantageous labor market situations. Thus, although our dynamic time-averaging model differs in many details, this conclusion and forces leading to it in the form of the importance of high elasticities at the extensive margin align with findings of Saez (2002).

Section 2 sets out our model, while Section 3 describes parameter calibration and estimation. Section 4 conveys mechanisms and forces at work. Section 5 analyzes tax reforms. Our analysis here extends Prescott's (2002) insight that the effects of taxation depend sensitively on whether the government spends tax revenues in ways that are close substitutes for private consumption or on public goods that are not. Section 6 offers concluding remarks.

2 The Model

Our model is a full-fledged time-averaging extension of the life-cycle, heterogeneous-agent framework with 1- and 2-person households in HKS. In the HKS model, both genders have intensive labor supply margins, but only females have an extensive margin. The HKS model exogenously imposes retirement at age 65 for both genders. We drop that assumption and instead include extensive margins of labor supply for both men and women. Thus, in our model both genders can choose to work after age 65. Both genders face endogenous wage profiles that depend on their years of labor market experience. To weaken older workers propensities to work, we follow Graves et al. (2023) and assume that efficiency units of experience depreciate with age and calibrated that to be especially noticable for workers after age 70. As for government policy, we drop HKS's assumption of a fixed unemployment benefit to women and replace HKS's fixed social security benefit to retirees with benefits that depend on a retiree's years worked as well as on an average of labor earnings among workers of ages 30-64 having the same characteristics as the retiree, i.e., gender, ability, and marital state. We retain most other components of HKS.[6]

2.1 Technology

A representative firm operates a Cobb-Douglas production function

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

where K_t is capital, L_t is the labor measured in efficiency units, and Z_t is labor-augmenting productivity. Physical capital evolves according to

$$K_{t+1} = (1-\delta)K_t + I_t,$$

where I_t is gross investment, and δ is the capital depreciation rate. Productivity Z_t grows deterministically according to $Z_t = (1+\mu)^t$, starting from $Z_0 = 1$. In each period, a representative firm rents labor and capital in amounts that maximize profits:

$$\Pi_t = Y_t - w_t L_t - (r_t + \delta)K_t.$$

In competitive equilibrium, factor prices equal marginal products:

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

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

We restrict attention to balanced growth equilibria. Exogenous technological progress generates persistent growth. Following King et al. (2002) and Trabandt & Uhlig (2011), we impose restrictions on preferences, the production technology, and government policies that allow us to work with stationary variables after standard transformations. Along a balanced growth path (BGP) $K^z = K_t/Z_t$ is constant. We define $w_t^z = w_t/Z_t$ and note that w_t^z and r_t are constant along a BGP. Therefore, we drop time subscripts for these variables as well.

[6] We have amended the HKS formulation of households' optimization problems. HKS correctly formulated the problem of a married couple in the form of a unitary household that places equal weights on spouses' continuation values in singlehood after a divorce. However, working backward, HKS used the value function of a unitary household to represent the value of the two individuals entering into that marriage. That meant that the spouses were randomizing over the genders they would take after a divorce. We instead deduce an authentic spouse-specific value function from the policy function of a married household together with the continuation value at a divorce by the appropriate spouse's gender-specific value function in singlehood. See Appendix A.4 for further discussion and comparisons to HKS.

2.2 Demographics

There are J overlapping generations of finitely lived households, with household age indexed by $j \in J$. Data show that family type is an important determinant of labor supply elasticities, so we model heterogeneity in family structure explicitly.[7] Households are either single (denoted by S) or married (denoted by M); single households are man or woman, denoted $\iota \in (m, w)$. Thus, there are 3 types of households: single males, single females, and married couples. We assume that within a married household, husband and wife are the same age. Households start life at age 20 and are in the labor force until at least age 65, the first age at which social security can be collected.

A model period is one year. The probability of dying before age 65 is zero. Households aged 65 and older face age-dependent probabilities of dying, $\pi(j)$ until age 100, when they die for sure. Husband and wife die simultaneously. A new generation consists of a unit measure of agents, with equal measures of men and women. Using $\omega(j) = 1 - \pi(j)$ to denote an age-dependent survival probability, application of a law of large numbers implies that the mass of agents of age $j \geq 65$ still alive is $\Omega_j = \prod_{q=65}^{q=j-1} \omega(q)$. A fraction of households leave unintended bequests that are allocated to surviving agents in the same cohort, so it is as if individuals in each cohort own shares of a mutual fund, with shares of dying owners being distributed proportionally among surviving owners. Surviving retirees of age j then earn gross return $(1 + r)/\omega(j - 1)$ on savings.

In addition to age and marital status, households are heterogeneous with respect to asset holdings k, exogenously determined permanent abilities $a \sim N(0, \sigma_a^{\iota 2})$ drawn at birth, years of labor market experience e, and idiosyncratic productivity shocks u. There are extensive and intensive labor supply margins. Individuals choose either to work or not to work (this is the extensive margin); conditional on working, they choose how much to work (this is the intensive margin). Married households jointly decide on how many hours to work, how much to consume, and how much to save. Individuals who participate in the labor market accumulate a year of labor market experience. Individuals choose when to retire. The earliest possible retirement age is 65. Retired individuals receive social security benefits and don't work.

Since labor supply decisions differ across family type and ages, we want an empirically plausible joint distribution of family types and ages. A tractable approach is to introduce marriage and divorce as exogenous shocks, as in Cubeddu & Rios-Rull (2003). Single households face age-dependent probabilities $M(j)$ of becoming married and married households face age-dependent probabilities $D(j)$ of divorce. Assortative matching in the marriage market means that there is a greater chance of marrying someone with similar ability. Thus, a

[7] Keane (2011) stresses the importance of marital status in shaping labor supply responses to taxes.

single male with ability a^m faces a probability $\phi^w(a|a^m;\varphi)$ of marrying a female of type a, and symmetrically, a female of type a^w marries a male of ability a with probability $\phi^m(a|a^w;\varphi)$. Parameter φ, calibrated in section 3, captures the amount of sorting in the marriage market, with $\varphi = 0$ standing in for perfectly random marriage and $\varphi = 1$ representing perfect sorting by permanent ability.[8]

2.3 Wages

An individual's wage depends on the aggregate wage per efficiency unit of labor, $w^z = \frac{w}{Z}$, and his or her endowment of efficiency units, which depends on the individual's gender, $\iota \in (m, w)$, ability, a, accumulated labor market experience, e, age, j, and an idiosyncratic shock u that follows an AR(1) process. Thus, setting aside effects of age, the wage of an individual with characteristics (a, e, u, ι) is

$$log(\widetilde{w}^z(a,e,u,\iota)) = log(w^z) + a + \gamma_0^\iota + \gamma_1^\iota e + \gamma_2^\iota e^2 + \gamma_3^\iota e^3 + u \tag{3}$$

$$u' = \rho^\iota u + \epsilon, \quad \epsilon \sim N(0, \sigma^2_{\epsilon^\iota}) \tag{4}$$

Parameters γ_0^ι encode average productivity, while γ_1^ι, γ_2^ι and γ_3^ι describe returns to experience for women and men. To describe depreciation of human capital in old age, let

$$\varepsilon(j) = \frac{1}{1 + \exp(\phi_1(j - \phi_2))} \leq 1 \tag{5}$$

be a multiplicative factor that transforms the human capital stock of an agent of age j into efficiency units.

An individual of age j's wage adjusted for human capital depreciation is:

$$w^z(a,e,u,\iota,j) = \widetilde{w}^z(a,e,u,\iota) \times \varepsilon(j).$$

2.4 Preferences

We model a married couple as a consolidated unit, a so-called unitary household, with the following one-period utility function that depends on joint consumption c, hours $n^m \in [0,1]$ worked by a husband, and hours $n^w \in [0,1]$ worked by a wife:

$$U^M(c, n^m, n^w) = \log(c) - \chi_M^m \frac{(n^m)^{1+\eta^m}}{1+\eta^m} - \chi_M^w \frac{(n^w)^{1+\eta^w}}{1+\eta^w} - F_M^m \cdot \mathbb{1}_{[n^m>0]} - F_M^w \cdot \mathbb{1}_{[n^w>0]}. \tag{6}$$

[8]Conditional on gender, age and permanent ability, a single household expects to draw a partner drawn from the joint distribution of age-specific characteristics of single people of the other gender. Thus, since permanent ability and assets are positively correlated for single females, a single male understands that if he were, by chance, to marry a high ability female, she would bring higher than average assets into the marriage.

Here F_M^ι is a fixed disutility from working positive hours. The indicator function $\mathbb{1}_{[n>0]}$ equals 0 when $n = 0$ and 1 when $n > 0$. In evaluating prospects after a possible divorce, a unitary household places equal weights on the partners' continuation values in singlehood. While married, both partners enjoy the same period utility in expression (6), i.e., they receive the same utility from joint consumption and share each other's disutility from working.

The period utility function for singles is:

$$U^S(c, n, \iota) = \log(c) - \chi_S^\iota \frac{(n)^{1+\eta^\iota}}{1+\eta^\iota} - F_S^\iota \cdot \mathbb{1}_{[n>0]} \tag{7}$$

Disutility of work and the fixed cost of work can differ by gender and marital status. In a model without participation margin, King et al. (2002) show that the above preferences are consistent with balanced growth. HKS demonstrate that this is also true in a model with a fixed utility cost from working positive hours and an operative extensive margin.

2.5 Government

The government runs a balanced budget period-by-period. It taxes workers and the representative firm at social security system tax rates τ_{ss} and $\tilde{\tau}_{ss}$, consumption at flat rate τ_c, capital income at flat rate τ_k, and labor at a progressive tax rate that we shall soon describe. The government spends for pure public consumption goods G_t, interest payments rB_t on the national debt, lump sum redistributions g_t, and social security benefits Ψ_t to retirees. We assume that there is some outstanding government debt, and that the government debt to output ratio, $B_Y = B_t/Y_t$, is constant over time. We assume that spending on public consumption is proportional to GDP, so $G_Y \equiv G_t/Y_t$ is constant. In the U.S., interest income is taxed together with labor income and the corporate tax code is non-linear. Nevertheless, we follow a common practice that approximates a capital income tax schedule with a flat tax.

We allow social security benefits to depend on an individual's gender, marital status pair $q \in \{M, S\}$, innate ability (level of education), and years of labor market experience. After reaching the official retirement age of 65, individuals decide whether to retire. If they choose to retire, they begin to collect social security pension payments that satisfy the formula

$$\Psi(\iota, q, a_i, e_i) = \psi_0 + \psi_1 \times AE(\iota, q, a_i) \times \min\{1, e_i/35\}, \tag{8}$$

where $AE(\iota, m, a_i)$ is average earnings of individuals with the indicated gender, marital status, and ability, where the average is over ages 30-64. The pension payment is increasing in experience up to 35 years of experience; ψ_0 is a minimum pension benefit, while ψ_1 determines how benefits increase with lifetime earnings.

In our benchmark model, a worker who chooses to work after age 65 receives no social security benefits. The implied implicit tax on the labor supply of individuals who have reached their retirement age can put some of them at a corner solution that tells them to retire at age 65. In subsection 4.4, we will study a modified version of the benchmark model under a social security reform that removes that implicit tax on working after age 65.

To model a non-linear labor income tax, we use a function of Benabou (2002) that Heathcote, Storesletten & Violante (2017) also used. This function makes the average tax rate on labor income y be $\tau(y) = 1 - \theta_0 y^{-\theta_1}$; parameters θ_0 and θ_1 govern the level and the progressivity of the tax system.

We use superscript Z to denote variables deflated by total factor productivity Z. Thus, we define deflated tax revenue from social security, labor, capital and consumption taxes, R^z, transfers, g^z, government consumption, G^z, and social security benefits, Ψ^z, as:

$$R^z = R_t/Z_t, \quad g^z = g_t/Z_t, \quad G^z = G_t/Z_t, \quad \Psi^z = \Psi_t/Z_t$$

Along a BGP these variables are constant shares of GDP. The government budget constraint (normalized by the level of technology) along a BGP is:

$$\Psi^z + g^z \left(45 + \sum_{j \geq 65} \Omega_j \right) + G^z + (r - \mu) B^z = R^z$$

The government spends resources on social security benefits, transfers, government consumption, and servicing outstanding government debt. It uses tax revenue to pay for that.

2.6 Recursive Formulation of Household Problem

A pre-retirement-age married household is characterized by the household's age j, its assets, k, the man's and the woman's experience levels, e^m, e^w, their transitory productivity shocks u^m, u^w and permanent ability levels a^m, a^w. Thus, the state vector for such a married household is $(k, e^m, e^w, u^m, u^w, a^m, a^w, j)$. The state vector for a single household is (k, e, u, a, ι, j). To formulate a household's problem along a BGP recursively, we define deflated household consumption and assets as $c^z = c_t/Z_t$ and $k^z = k_t/Z_t$. Since ratios of aggregate variables to productivity, Z_t, and to aggregate output are constant along the BGP, we posit that household-level variables, c^z and k^z, do not depend on calendar time, we omit the time subscripts for them.

For married couples, we keep track of two value functions. We follow Cubeddu & Rios-Rull (2003) and assume that during marriage, both partners obey decision rules chosen by a unitary household, in particular, ones that attain the optimal value function that satisfies the following Bellman equation for households prior to age 65:

$$V^M(k^z, e^m, e^w, u^m, u^w, a^m, a^w, j) = \max_{c^z,(k^z)',n^m,n^w} \Big[U^M(c^z, n^m, n^w)$$
$$+ \beta(1 - D(j))E_{(u^m)',(u^w)'}\big[V^M((k^z)', (e^m)', (e^w)', (u^m)', (u^w)', a^m, a^w, j + 1)\big]$$
$$+ \frac{1}{2}\beta D(j)E_{(u^m)',(u^w)'}\big[V^S((k^z)'/2, (e^m)', (u^m)', a^m, m, j + 1) + V^S((k^z)'/2, (e^w)', (u^w)', a^w, w, j + 1)\big]\Big] \tag{9}$$

where maximization is subject to

$$c^z(1 + \tau_c) + (k^z)'(1 + \mu) = k^z(1 + r(1 - \tau_k)) + 2g^z + Y^L$$
$$Y^L = \left(Y^{L,m} + Y^{L,w}\right)\left(1 - \tau_{ss} - \tau_l^M\left(Y^{L,m} + Y^{L,w}\right)\right)$$
$$Y^{L,\iota} = \frac{n^\iota w^z(a^\iota, e^\iota, u^\iota, \iota, j)}{1 + \tilde{\tau}_{ss}},\ \iota = m, w$$
$$(e^m)' = e^m + \mathbb{1}_{[n^m>0]}, \quad (e^w)' = e^w + \mathbb{1}_{[n^w>0]},$$
$$n^m \in [0, 1], \quad n^w \in [0, 1], \quad (k^z)' \geq 0, \quad c^z > 0$$

Y^L is household labor income, composed of labor incomes that spouses receive during the working phase of their life, τ_{ss} and $\tilde{\tau}_{ss}$ are social security contributions paid by employee and employer.

In addition to value function (9), we want value functions of partners within couples. We require these objects to compute the values of getting married for single individuals. To define them, let $\widehat{c}^z(.), (\widehat{k}^z(.))', \widehat{n}^m(.), \widehat{n}^w(.)$ be the optimal policy functions for consumption, savings and hours worked that attain the value function (9) for married households at a given state vector $(\cdot)$. Value functions of partners within couples are:

$$\widetilde{V}^M(k^z, e^m, e^w, u^m, u^w, a^m, a^w, \iota, j) = \Big[U^M(\widehat{c}^z(.), \widehat{n}^m(.), \widehat{n}^w(.))$$
$$+ \beta(1 - D(j))E_{(u^m)',(u^w)'}\big[\widetilde{V}^M((\widehat{k}^z(.))', e^m + \mathbb{1}_{[\widehat{n}^m(.)>0]}, e^w + \mathbb{1}_{[\widehat{n}^w(.)>0]}, (u^m)', (u^w)', a^m, a^w, \iota, j + 1)\big]$$
$$+ \beta D(j)E_{(u^\iota)'}V^S((\widehat{k}(.)^z)'/2, e^\iota + \mathbb{1}_{[\widehat{n}^\iota(.)>0]}, (u^\iota)', a^\iota, \iota, j + 1)\Big] \tag{10}$$

where V^S is the value function of a single household to be defined below in equation (11). No optimisation appears on the right side of equation (10): we simply plug in optimal decisions that attain value function (9) for couples.

A single person of gender ι knows probabilities of marrying someone of opposite gender

$-\iota$. That person's value function satisfies the Bellman equation:

$$V^S(k^z, e, u, a, \iota, j) = \max_{c^z,(k^z)',n} \Big[U^S\left(c^z, n, \iota\right)$$
$$+ \beta(1 - M(j))E_{u'}\left[V^S((k^z)', e', u', a, \iota, j+1)\right]$$
$$+ \beta M(j) E_{(k^{-\iota})', e^{-\iota}, (u^m)', (u^w)', a^{-\iota}}\left[\widetilde{V}^M((k^z)' + (k^{-\iota})', (e^w)', (u^m)', (u^w)', a^m, a^w, \iota, j+1)\right]\Big] \tag{11}$$

where maximization is subject to

$$c^z(1+\tau_c) + (k^z)'(1+\mu) = k^z\left(1 + r(1-\tau_k)\right) + g^z + Y^L$$
$$Y^L = \left(Y^{L,\iota}\right)\left(1 - \tau_{ss} - \tau_l^S\left(Y^{L,\iota}\right)\right)$$
$$Y^{L,\iota} = \frac{n^\iota w^z\left(a^\iota, e^\iota, u^\iota, \iota, j\right)}{1 + \tilde{\tau}_{ss}},$$
$$(e^\iota)' = e^\iota + \mathbb{1}_{[n^\iota > 0]},$$
$$n^\iota \in [0,1], \quad (k^z)' \geq 0, \quad c^z > 0$$

$E_{(k^{-\iota})', e^{-\iota}, (u^m)', (u^w)', a^{-\iota}}$ is a conditional expectation over the joint distribution of characteristics of a partner in the case of marriage as well as this individual's labor productivity next period. The joint distribution is conditional on the individual's age and permanent ability.[9]

Two important things occur when an individual reaches age 65: (1) the individual chooses whether to retire; (2) thereafter there will be neither marriage or divorce. An individual who retires starts collecting pension payments. Individuals of ages 65 and older ($j \geq 65$) carry a state variable $\mathit{\Lambda} \in \{0, 1\}$ that indicates retirement status. Retirement is irreversible, meaning that somene cannot retire, receive benefits, then return to work. The value function

[9] There is perfect assortative matching with respect to age, and, to some (calibrated) extent, with respect to permanent ability.

of married couples aged 65 and older satisfies the Bellman equation:

$$V^M(k^z, e^m, e^w, u^m, u^w, a^m, a^w, \mathit{\Lambda}^m, \mathit{\Lambda}^w, j) = \max_{c^z,(k^z)',n^m,n^w,(\mathit{\Lambda}^m)',(\mathit{\Lambda}^w)'} \Big[U^M\left(c^z, n^m, n^w\right)$$

$$+ \beta E_{(u^m)',(u^w)'}\big[V^M((k^z)', (e^m)', (e^w)', (u^m)', (u^w)', a^m, a^w, (\mathit{\Lambda}^m)', (\mathit{\Lambda}^w)', j+1)\big] \tag{12}$$

where maximization is subject to

$$c^z(1+\tau_c) + (k^z)'(1+\mu) = k^z\left(1 + r(1-\tau_k)\right) + 2g^z + Y^L + \mathit{\Psi}^{zm}\mathit{\Lambda}^m + \mathit{\Psi}^{zf}\mathit{\Lambda}^f$$

$$Y^L = \left(Y^{L,m} + Y^{L,w}\right)\left(1 - \tau_{ss} - \tau_l^M\left(Y^{L,m} + Y^{L,w}\right)\right)$$

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

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

$$\text{If } \mathit{\Lambda}^\iota = 0, \quad n^\iota \in [0,1], \ \text{else } n^\iota = 0,$$

$$(k^z)' \geq 0, \quad c^z > 0,$$

$$\text{If } \mathit{\Lambda}^\iota = 0, \quad (\mathit{\Lambda}^\iota)' \in \{0,1\}, \ \text{else } (\mathit{\Lambda}^\iota)' = \mathit{\Lambda}^\iota.$$

Since no marriages or divorces occur after age 65, we no longer need to keep track of value functions of individuals within couples. The value function of a single household, aged 65 and older, satisfies the Bellman equation:

$$V^S(k^z, e, u, a, \iota, \mathit{\Lambda}, j) = \max_{c^z,(k^z)',n,(\mathit{\Lambda})'} \Big[U^S\left(c^z, n, \iota\right)$$

$$+ \beta E_{u'}\big[V^S((k^z)', e', u', a, \iota, (\mathit{\Lambda})', j+1)\big] \tag{13}$$

where maximization is subject to

$$c^z(1+\tau_c) + (k^z)'(1+\mu) = k^z\left(1 + r(1-\tau_k)\right) + g^z + Y^L + \mathit{\Psi}^z\mathit{\Lambda}$$

$$Y^L = \left(Y^{L,\iota}\right)\left(1 - \tau_{ss} - \tau_l^S\left(Y^{L,\iota}\right)\right)$$

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

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

$$\text{If } \mathit{\Lambda} = 0, \quad n^\iota \in [0,1], \ \text{else } n^\iota = 0,$$

$$(k^z)' \geq 0, \quad c^z > 0,$$

$$\text{If } \mathit{\Lambda} = 0, \quad (\mathit{\Lambda})' \in \{0,1\}, \ \text{else } (\mathit{\Lambda})' = \mathit{\Lambda}.$$

2.7 Equilibrium

Our model is an instance of an equilibrium Markov process that contains (i) a collection of decision makers, (ii) associated Markov decision problems defined over a common state space, and (iii) budget and resource constraints that bind together decision makers' decision problems. Appendix A.2 describes these three components and how the equilibrium concept assembles them in a coherent way. By indicating agents' Bellman equations in the previous subsection, we have described their Markov decision problems. Because individual agents' Markov decision problems depend on state variables that they take as exogenous, but whose laws of motion are actually equilibrium outcomes, computing our model's equilibrium process involves a nested fixed point algorithm. For example, a single person cares about characteristics of prospective partners, so a single person's Markov decision problem includes a description of the motion of those state variables. Appendix A.2 also provides some details about our computational procedures.

We assume that the equilibrium Markov process has a unique stationary distribution in which the cross-section distribution across agent types is time-invariant and gear our computational algorithm to find it. We confine our quantitative analysis to statements about that stationary distribution.[10].

3 Calibration

We calibrate parameters to match selected moments from 2001-2007 U.S. data. We calibrate parameters listed in Table 1 directly to their empirical counterparts; we don't need to use our model to calibrate them. We calibrated the 11 parameters in Table 2 using an exactly identified simulated method of moments (SMM) approach.

3.1 Technology

We set the capital share parameter α to 1/3 and choose the depreciation rate to match an investment-to-capital ratio of 9.88% in U.S. data.

3.2 Demographics and Transitions Between Family Types

The demographic structure of the model is determined by the unit mass of newborn households and the death probabilities of retirees. We obtain the latter from the National Center for Health Statistics.

There are three family types: (1) single males; (2) single females; (3) married couples. To calculate age-dependent probabilities of transitions between married and single, we use U.S. data from the CPS March supplement, covering years 1999 to 2001. We assume stationarity; thus, although we allow probabilities of transitioning between family types to depend on an individual's age, we rule out dependence on birth cohort. We compute the probability $M(j)$ of getting married and the probability $D(j)$ of getting divorced at age j from the transition

[10] To focus on a BGP, we scale all growing variables by the factor Z_t.

equations:

$$\bar{M}(j+1) = (1-\bar{M}(j))M(j) + \bar{M}(j)(1-D(j)),$$
$$\bar{D}(j+1) = \bar{D}(j)(1-M(j)) + \bar{M}(j)D(j).$$

Exogenous spousal sorting by ability is governed by a parameter φ that we estimate with our SMM procedure. We have five discrete ability types in our model and posit that these types resemble the five levels of education in the CPS (2001-2007). We match a 0.646 correlation of education levels for married couples.[11]

3.3 Wages

We estimate experience profiles for male and female wages and the exogenous processes for idiosyncratic shocks using the PSID from 1968-1997. After 1997, it is not possible to obtain years of actual labor market experience from the PSID. Appendix A.5 describes our estimation procedure in more detail. We use a 2-step approach to control for selection into the labor market, as described in Heckman (1976, 1979). After estimating returns to experience for males and females, we use residuals from the regressions and the panel data structure of the PSID to estimate parameters ρ_ϵ^ι and σ_ϵ^ι for the productivity shock processes and the variances σ_a^ι of individual abilities. We estimate the mean wage parameters γ_0^w and γ_0^m together with other model parameters via SMM. The associated data moments are the ratio between male and female earnings and the average wage of working individuals, which we normalize to 1 in the model.

As for the logistic function (5) that determines human capital depreciation in old age, we set the parameter ϕ_1 that controls the speed of depreciation to the same value used by Graves et al. (2023); we set ϕ_2, the age at the inflection point of the function, to 85.

3.4 Preferences

One-period utility functions for both family types are given in equations (6) and (7). We set the discount factor β to match the capital-output ratio K/Y, taken from the BEA. We choose four different values for the participation costs, by gender and marital state, to match

[11] Specifically, prior to marriage an individual of earnings type a draws random marriage quality $\varsigma \sim U[0,1]$. His/her marriage quality rank M_n is then determined by

$$M_n = (1-\varphi)\varsigma + \varphi a. \tag{14}$$

Then all individuals of the same gender are ranked according to M_n and matched with exactly the same rank of the opposite gender. If $\varphi = 0$, marriage is random, and if $\varphi = 1$, marriages are perfectly sorted by spousal ability a. Appendix A.6 contains the details of this construction, which, conditional on own ability a, induces a distribution over spousal abilities (and associated distribution over the other payoff-relevant state variables of future partners) that permits singles to rationally form expectations.

employment rates of married and single males and females aged 20-64, taken from the CPS.

As explained by Keane (2011), economists disagree about sizes of Frisch elasticities of labor supply. Nevertheless, there seems to be a consensus that female labor supply is much more elastic than male labor supply.[12] We set the intensive margin Frisch elasticity of male labor supply $1/\eta^m = 0.4$, in line with recent work in quantitative macroeconomics; see Guner et al. (2012). We set the intensive margin Frisch elasticity of female labor supply $1/\eta^w$ to 0.8.

3.5 Taxes and Social Security

As described in Section 2.5 we employ the Benabou (2002) labor income tax function $\tau(y) = 1 - \theta_0 y^{-\theta_1}$. We follow HKS and use U.S. labor income tax data provided by the OECD to estimate the parameters θ_0 and θ_1 for different family types.

For the government-run social security system we assume that payroll taxes for the employee, τ_{SS}, and the employer, $\tilde{\tau}_{SS}$ are flat taxes, and use the rate from the bracket covering most incomes in the U.S., 7.65% for both τ_{SS} and $\tilde{\tau}_{SS}$. We follow Trabandt & Uhlig (2011) and set $\tau_k = 36\%$ and $\tau_c = 5\%$ for consumption and capital income tax rates.

3.6 Pensions

Sizes of pension payments depend on an individual's gender, marital status, fixed ability type, and accumulated experience, as specified in equation (8). To calibrate parameters ψ_0 and ψ_1, we use three data moments obtained from the OECD publication *Pensions at a glance*, (2007): i) the average replacement rate across all individuals is 40%, ii) the average pension of someone with income of 0.5 times average earnings (0.5AE) is 0.276AE, iii) the average pension of someone with income of 2.0 times average earnings (2.0AE) is 0.643AE. We use this information to pin down $\psi_0 = 0.1537$, $\psi_1 = 0.2447$.

Before the social reform that we shall describe below, if an individual 65 or older decides to work, he or she cannot collect pension payments, a feature that imposes an implicit tax on working and can induce some people to retire via a corner solution to their choice problem. We will study the effects on the aggregate labor supply elasticity of reforms that remove this implicit tax.

3.7 Transfers and Government Consumption

There is an ongoing debate about the share of government spending that transfers to households comprise. Here we assume that most government spending is on public goods. In the calibrated equilibrium we give all individuals the same small lumpsum transfer that totals 1% of GDP. All other government expenditures are on the pure public consumption good G.

[12] Blundell et al. (2016) estimated the intensive margin Frisch elasticity for men and women between the ages of 30 and 57 as 0.53 and 0.85, respectively.

Table 1: Parameters Calibrated Outside of the Model

Parameter	Value	Description	Target
$1/\eta^m, 1/\eta^w$	0.4, 0.8	$U^M(c, n^m, n^w) = \log(c) - \chi_M^m \frac{(n^m)^{1+\eta^m}}{1+\eta^m} - \chi_M^w \frac{(n^w)^{1+\eta^w}}{1+\eta^w} - F_M^w \cdot \mathbb{1}_{[n^w>0]}$	Literature
$\gamma_1^m, \gamma_2^m, \gamma_3^m$	$0.061, -1.06 * 10^{-3}, 9.30 * 10^{-6}$	$w_t(a_i, e_i, u_i) = w_t e^{a_i+\gamma_0^m+\gamma_1^m e_i+\gamma_2^m e_i^2+\gamma_3^m e_i^3+u_i}$	PSID (1968-1997)
$\gamma_1^w, \gamma_2^w, \gamma_3^w$	$0.078, -2.56 * 10^{-3}, 2.56 * 10^{-5}$	$w_t(a_i, e_i, u_i) = w_t e^{a_i+\gamma_0^w+\gamma_1^w e_i+\gamma_2^w e_i^2+\gamma_3^w e_i^3+u_i}$	
$\sigma_\epsilon^m, \sigma_\epsilon^w,$	0.322, 0.310	$u' = \rho_{jg} u + \epsilon$	
$\rho_\epsilon^m, \rho_\epsilon^w$	0.396, 0.339	$\epsilon \sim N(0, \sigma_{jg}^2)$	
σ_a^m, σ_a^w	0.315, 0.385	$a^\iota \sim N(0, \sigma_{a_m}^2)$	
$\theta_0^S, \theta_1^S, \theta_0^M, \theta_1^M$	0.8177, 0.1106, 0.9420, 0.1577	$ya = \theta_0 y^{1-\theta_1}$	OECD tax data
τ_k	0.36	Capital tax	Trabandt & Uhlig (2011)
$\tau_{ss}, \tilde{\tau}_{ss}$	(0.0765, 0.0765)	Social Security tax	OECD
τ_c	0.05	Consumption tax	Trabandt & Uhlig (2011)
B/Y	0.6185	National debt	Government debt (World Bank)
$\omega(j)$	Varies	Survival probabilities	NCHS
$M(j)$, $D(j)$	Varies	Marriage and divorce probabilities	CPS
μ	0.0200	Output growth rate	Trabandt & Uhlig (2011)
δ	0.0788	Depreciation rate	$I/K - \mu$ (BEA)
α	1/3	$Y_t(K_t, L_t) = K_t^\alpha [Z_t L_t]^{1-\alpha}$	Historical capital share
ϕ_1	0.2	speed of human capital depreciation in old age	Graves et al. (2023)
ϕ_2	85	age at inflection point, human capital depreciation	
ψ_0	0.1537	minimum pension benefit	"Pensions at a glance" (2007)
ψ_1	0.2447	increase in pension benefits with lifetime earnings	

Table 2: Parameters Calibrated Endogenously

Parameter	Value	Description	Moment	Moment Value
γ_0^m	0.068	$w_t(a_i, e_i, u_i) = w_t e^{a_i+\gamma_0^\iota+\gamma_1^\iota e_i+\gamma_2^\iota e_i^2+\gamma_3^\iota e_i^3+u_i}$	Gender earnings ratio	1.569
γ_0^f	-0.069		Average Earnings (AE)	1.000
β	1.007	Discount factor	K/Y	2.640
$\log(F_M^w)$	-1.525	$U^M(c, n^m, n^w) = \log(c) - \chi_M^m \frac{(n^m)^{1+\eta^m}}{1+\eta^m} -$	Married fem employment	0.676
χ_M^w	5.94	$\chi_M^w \frac{(n^w)^{1+\eta^w}}{1+\eta^w} - F_M^m \cdot \mathbb{1}_{[n^m>0]} - F_M^w \cdot \mathbb{1}_{[n^w>0]}$	Married female hours	0.224 (1225 h/year)
$\log(F_M^m)$	-0.507		Married male employment	0.879
χ_M^m	17.13		Married male hours	0.360 (1965 h/year)
$\log(F_S^w)$	-0.147	$U^S(c, n, \iota) = \log(c) - \chi_S^\iota \frac{(n)^{1+\eta^\iota}}{1+\eta^\iota}$	Single fem. employment	0.760
χ_S^w	12.90	$-F_S^\iota \cdot \mathbb{1}_{[n>0]}$	Single female hours	0.251 (1371 h/year)
$\log(F_S^m)$	0.382		Single male employment	0.799
χ_S^m	39.95		Single male hours	0.282 (1533 h/year)
φ	0.105	$M_n = (1-\varphi)\varsigma + \varphi a$	$corr(a^m, a^w)$	0.646

3.8 Estimation Method

Twelve model parameters are estimated using an exactly identified simulated method of moments. We minimize the squared percentage deviation between simulated model statistics and the twelve data moments in column 5 of Table 2. Let $\Theta = \{\gamma_0^m, \gamma_0^f, \beta, F_M^w, \chi_M^w, F_M^m, \chi_M^m, F_S^w, \chi_S^w, F_S^m, \chi_S^m, \varphi\}$, and let $V(\Theta) = (V_1(\Theta), \ldots, V_{16}(\Theta))'$ and $V_i(\Theta) = (\bar{m}_i - \hat{m}_i(\Theta))/\bar{m}_i$, which measures a percentage difference between empirical and simulated moments. We set Θ to the minimizer of $V(\Theta)'V(\Theta)$. Table 2 summarizes estimated parameter values and data moments. We match all moments exactly, so $V(\Theta)'V(\Theta) = 0$.

4 Mechanics

4.1 Sources of individual fortunes

Exogenous stochastic marital dynamics, including assortative matching in terms of ability types, shape an individual's lifetime utility. Making marital dynamics exogenous helps us isolate and highlight how time averaging determines individuals' and couples' decisions about labor supply, consumption, and savings.

Spouses are the same ages and die simultaneously. Figure 1 depicts marriage and divorce probabilities at different ages. Figure 2 shows fractions of singles at different ages. After age 65, the fraction of singles remain constant since divorces and new marriages stop.

An individual's gender affects its lifetime utility. A single individual has a gender-specific disutility of working, while a married couple shares the same utility function over the couple's consumption and the couple's labor supplies. In addition to gender-specific permanent ability types and the stochastic process for idiosyncratic wage shocks, the wage of an individual depends on a gender-specific labor market experience profile displayed in Figure 3.

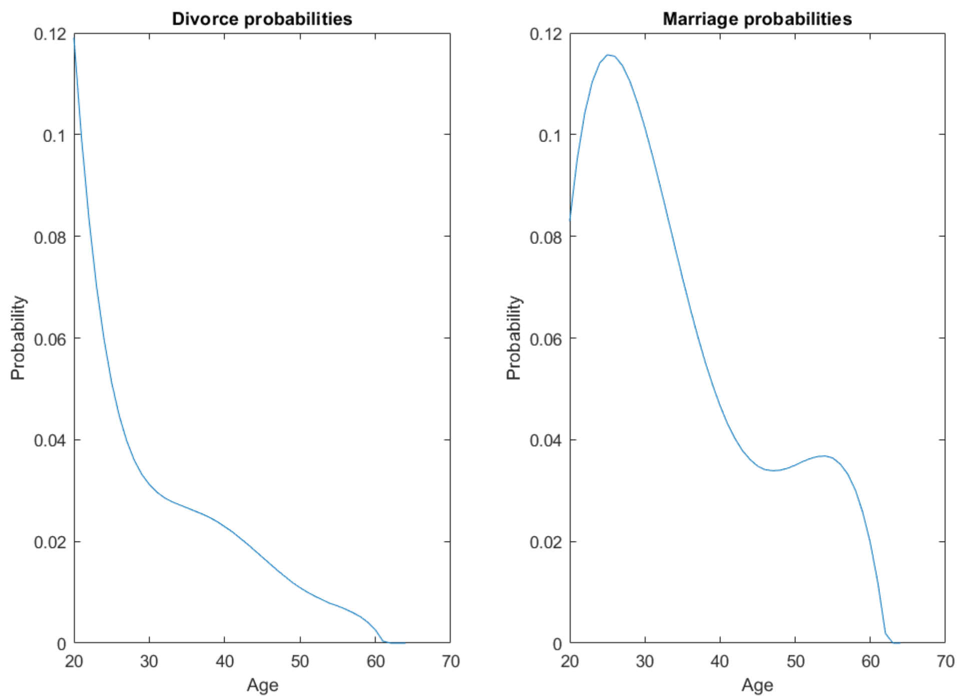


Figure 1: Divorce and marriage probabilities by age

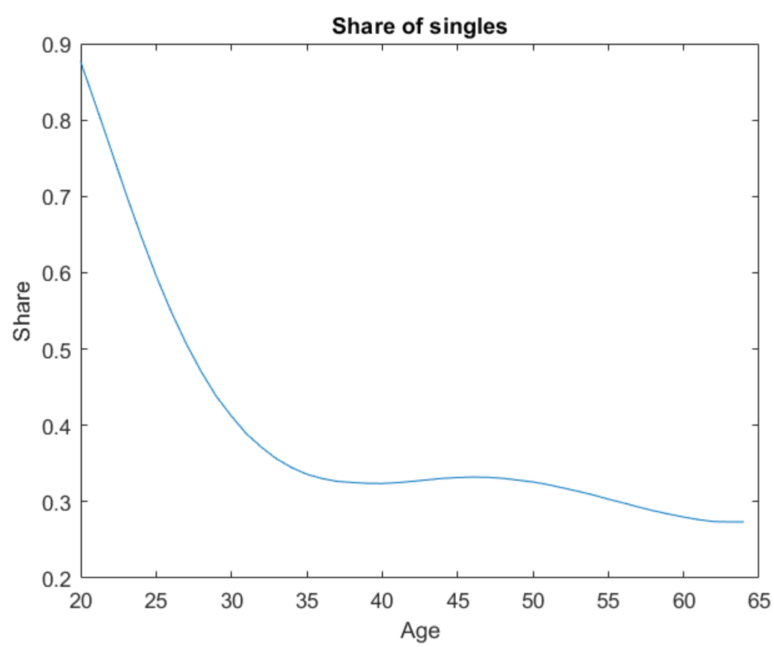


Figure 2: Share of singles by age

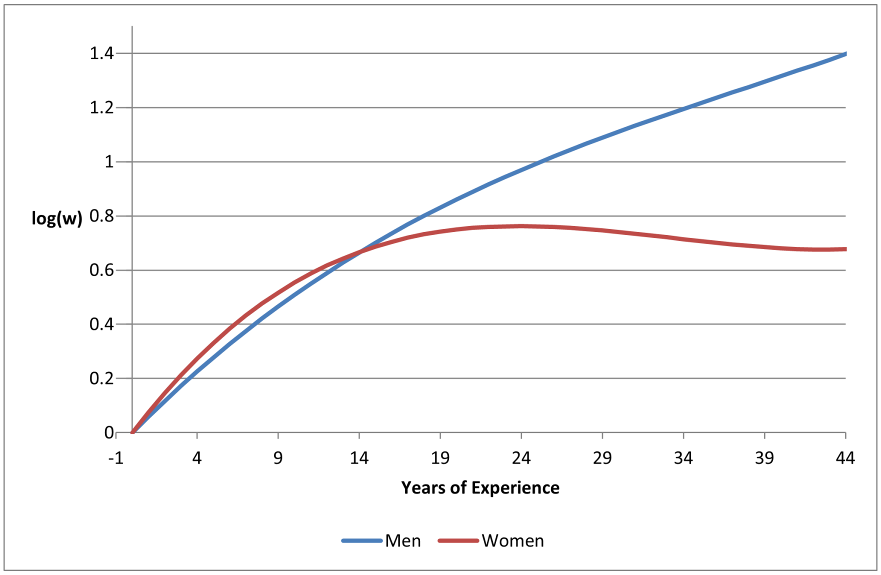


Figure 3: Labor market experience component of wages by gender and years of experience

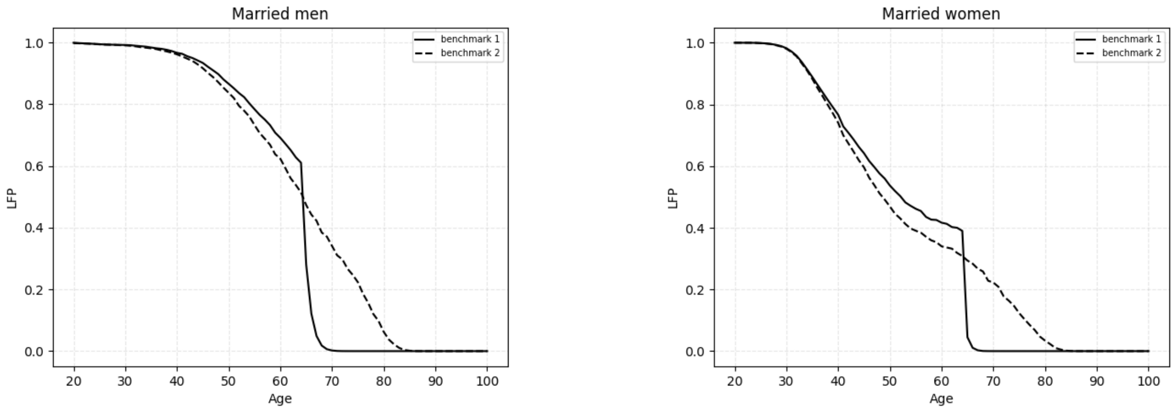
4.2 Benchmark 1 economy

As indicated by the solid lines in Figures 4 and 5, our time-averaging version of HKS can reproduce the outcome of HKS that people retire by age 65. The main features that let our model attain this outcome are parameterizations of fixed disutilities of working and a social security system that mimics an earlier system of the U.S. that specifiied that working beyond age 65 meant that some benefits would be lost.[13] In subsection 4.4, we study consequences of a social security reform that allows individuals to collect their benefits from age 65 whether or not they retire. The composition of married earners of different ages is shown in panel A of Figure 6; either both spouses work, or only the man or the woman works, or neither spouse works.

In addition to gender, age, and permanent ability, decision rules are functions of marital state, years of labor market experience, asset holdings, and idiosyncratic productivity shocks. To illustrate how consumption, savings, and labor supplies evolve over the life cycle in our time-averaging model, we devise the following thought experiment. We study a special agent who ends up with a time invariant marital state and time invariant idiosyncratic productivity shock.[14]

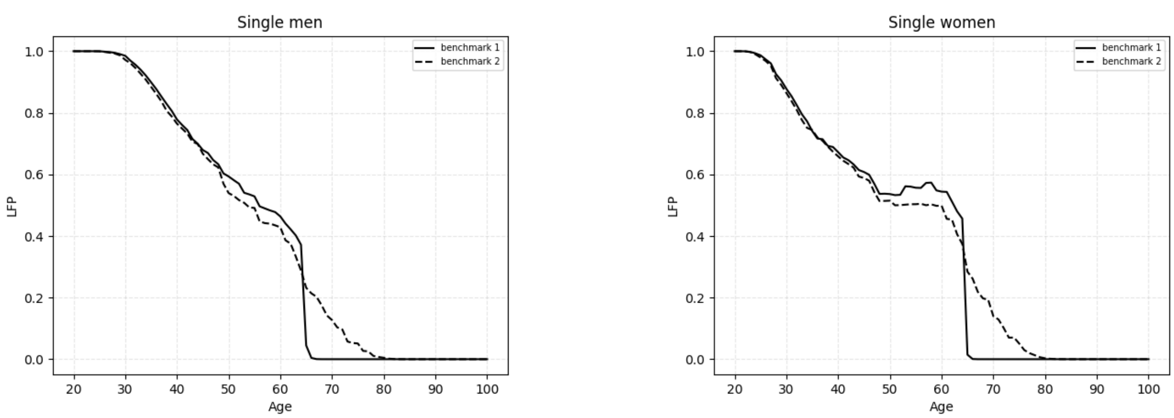
[13]We justify our assumption that social security benefits not collected after age 65 are a complete loss to a worker by referring to Schulz (2001, pp. 141-2), who described how this was actually the situation in the U.S. social security system between 1950 and 1972, after the 1950 suspension of an earlier provision of a 1 percent increase in benefits for each year of delayed retirement. After 1972, a delayed retirement credit was reintroduced, but it is only with rules that recently became effective that the compensation is high enough for there to be no loss in the actuarial value of a worker's lifetime benefits.

[14]In constructing the section 2 decision rules, the agent foresaw other possible outcome paths.



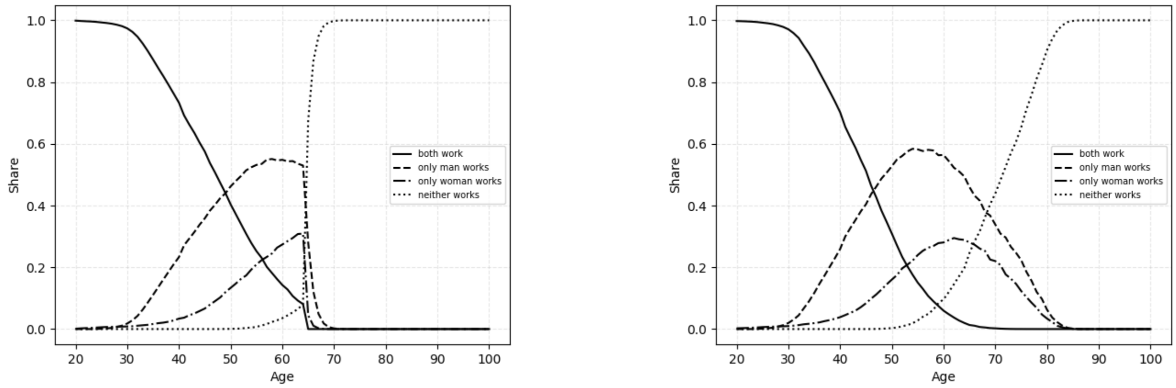
(a) men (b) women

Figure 4: Labor force participation in benchmark 1 economy and in social security reform benchmark 2 economy by married men (Panel A) and married women (Panel B)



(a) men (b) women

Figure 5: Labor force participation in benchmark 1 economy and under social security reform benchmark 2 economy by single men (Panel A) and single women (Panel B)

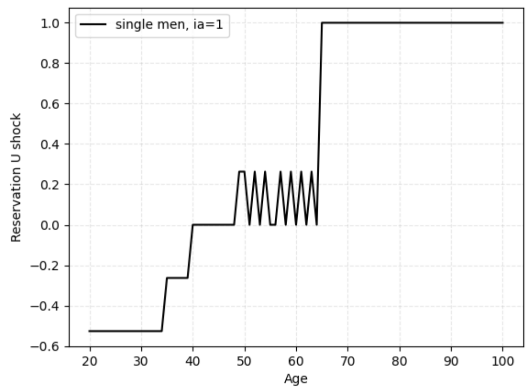


(a) Benchmark 1 economy (b) Benchmark 2 economy

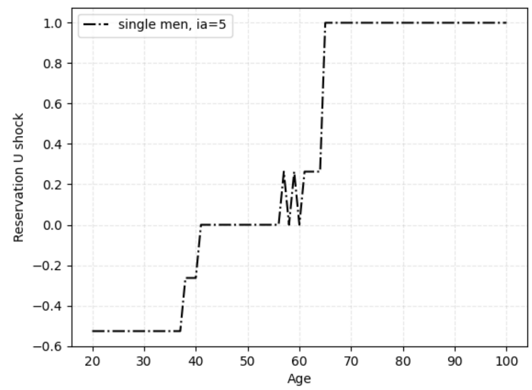
Figure 6: Composition of married couples' labor supplies in benchmark 1 economy (Panel A) and in social security reform benchmark 2 economy (Panel B)

To study agents who fare especially poorly, we focus on a single man of the lowest ability type who experiences a life of singlehood and has an idiosyncratic productivity shock always equal to its median value of $log(1) = 0$. The solid lines in Figure 7 depict his choice of reservation productivity at each age in panel A (where a value of 1 means that no emploment opportunity is acceptable) and the resulting labor force participation in panel C, either to work (value 1) or not to work (value 0). The solid lines in Figure 8 depict his associated decisions to consume in panel A and how many assets to hold in panel B. As a contrast, we also show that same thought experiment for a single man of the highest ability type (dashed lines) in Panels B and D of Figure 7 and Figure 8.

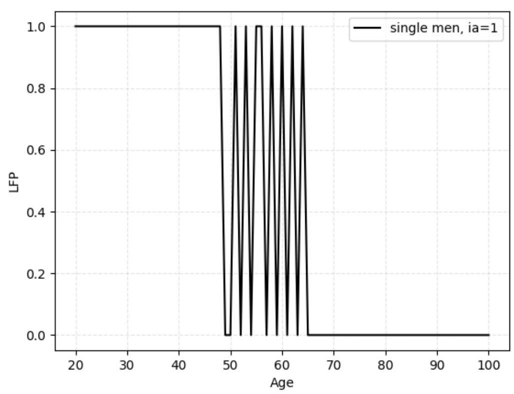
Comparing single men of lowest and highest abilities reveals a couple of striking similarities. Both men stop working at age 65, since they both set the reservation productivity equal to 1 in panels A and B of Figure 7, which exceeds the highest productivity shock (and that we use to indicate that 'no employment opportunity is acceptable'). This outcome is not very surprising since we parameterized the model to make most agents retire by age 65: rules of the social security system put many agents at a corner solution that tells them to retire at age 65. Another similarity is more surprising: in spite of having very different consumption and asset holdings in Figure 8, both men have similar reservation productivities throughout their working lives. An explanation for those similar choices is threefold: (i) different abilities manifest as multiplicative shifts in an otherwise common male-specific labor market experience profile in Figure 3; (ii) the social security benefit is scaled by an indicator of an agent's past labor earnings, so benefits are similar multiples of past labor earnings for both men; and (iii) the utility function is consistent with balanced growth. Such a utility



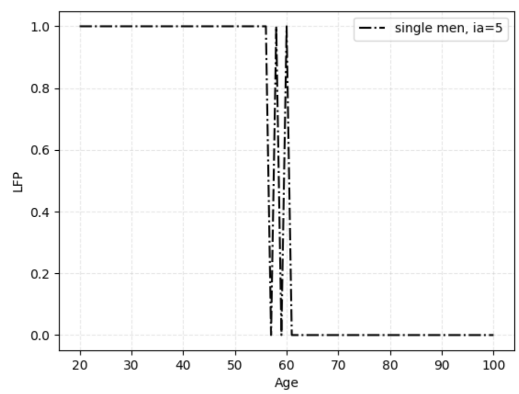
(a) reservation productivity, lowest ability



(b) reservation productivity, highest ability

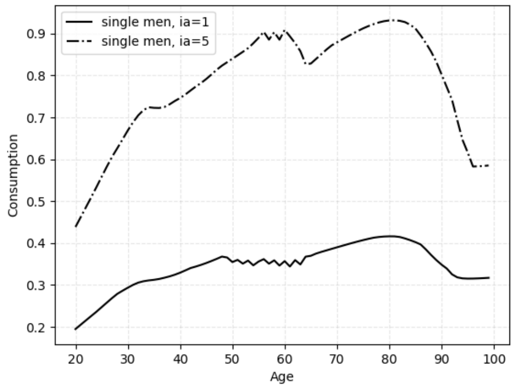


(c) LFP, lowest ability

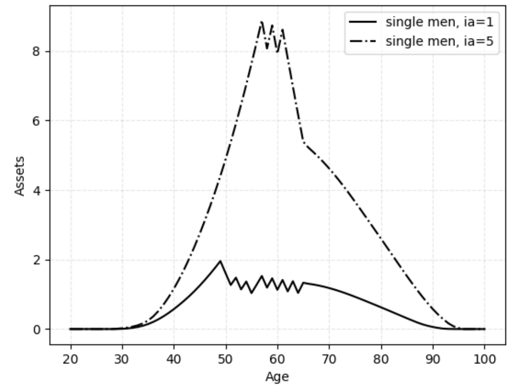


(d) LFP, highest ability

Figure 7: Reservation productivity (Panels A and B) and labor force participation (Panels C and D) of single men of lowest and highest abilities, respectively, who unknowingly experience lives of singlehood and an idiosyncratic productivity shocks equal to a median value equal to $log(1) = 0$.



(a) consumption



(b) asset holdings

Figure 8: Consumption (Panel A) and asset holdings (Panel B) of single men of lowest and highest abilities, respectively, who unknowingly experience lives of singlehood and an idiosyncratic productivity shocks equal to a median value of $log(1) = 0$.

function makes the level of earnings *per se* irrelevant so long as other relevant conditions are equivalent, such as similar elasticities of earnings to accumulated working time and a similar replacement rate in the social security system.

Chattering of reservation productivities and consequently of labor market participations at the end of men's working lives portrayed in Figure 7 is a natural outcome in a stochastic time-averaging model when a person wants to sustain optimal precautionary and/or retirement savings. An individual increases its labor supply in order to take advantage of favorable opportunities for replenishing savings after voluntary episodes of not working have reduced its asset holdings.

4.3 How tax revenues are spent matters

In an employment-lottery framework, Prescott (2002) emphasized that effects of taxation depend on whether a government spends tax revenues on close substitutes for private consumption or on public goods that are not close substitutes. Here we conduct a corresponding analysis in our time-averaging model.

Prescott said that most tax revenues are spent for goods and services that substitute perfectly for private consumption and therefore modelled government expenditures as lump-sum transfers to households. Temporarily embracing Prescott's assumption, we explore effects of the following tax and tranfer scheme in our benchmark 1 model. While keeping our present system of taxation, we introduce an extra flat-rate tax $\bar{\tau}$ that is levied on what had been agents' after-tax labor income. Thus, if that extra flat-rate tax is set equal to zero, we are back to the earlier equilibrium of our benchmark 1 economy; if that tax rate is set equal to 100 percent, agents keep nothing of their labor incomes. We consider two alternatives for how the government uses the revenues collected from levying the extra tax rate: either they are handed back as an equal lump-sum transfer to all agents in the economy, or they are spent on our pure public good G. In both cases, we adopt the auxiliary assumption that social security benefits are also reduced by the extra tax rate.

Figure 9 shows tax revenues raised by levying the extra tax $\bar{\tau}$ when tax revenues are handed back as lump-sum transfers (solid line) or spent on pure public goods (dashed line).[15] Much smaller tax revenues are collected along the solid Laffer curve because the lump-sum transfer cancels the income effect of a higher tax rate $\bar{\tau}$. That gives the substitution effect full rein to reduce individuals' labor supplies. These two Laffer curves reconfirm Prescott's (2002, p. 7) assertion that "the assumption that the tax revenues are given back to households either as transfers or as goods and services [that are good substitutes to private expenditures] matters. If these revenues are used for some public good or are squandered, private consumption will fall, and the tax wedge will have little consequence for labor supply." Nevertheless, because capital formation is affected in a general equilibrium, the extra tax wedge $\bar{\tau}$ brings distortions that increase along with the tax rate. To examine how much of the distortions operate through capital formation, we compute Laffer curves for a small open-economy (or "partial equilibrium") version of our model in which the interest rate is held constant at the benchmark 1 equilibrium rate. Dotted (light solid) lines in Figure 9 portray these Laffer curves without (with) lump-sum rebates. With lump-sum rebating of tax revenues, partial and general equilibrium outcomes are practically indistinguishable, i.e., the light and dark solid lines overlap almost perfectly in Figure 9. We'll explain this after we discuss outcomes with rebates.

To shed light on sources of differences between partial and general equilibrium Figure 9 Laffer curves without lump-sum rebates, we start by quoting a passage from Graves et al. (2023, Section 5.1):

> Consider a standard laissez-faire growth model with preferences consistent with balanced growth, as is true for our utility function [(6) and (7) in our present paper]. A permanent decline in a multiplicative productivity parameter would

[15] Note that the tax revenues from levying the extra tax $\bar{\tau}$ are in general higher than the change in total revenues from labor income taxation. Namely, smaller tax revenues can be expected to be raised from the benchmark 1 taxation of labor income whenever a higher tax rate $\bar{\tau}$ causes labor supplies and consequently aggregate labor income to shrink. Such losses of benchmark 1 tax revenues do not affect our calculation of a lump-sum transfer. Our tax experiment risks bankrupting the government, so as we raise the tax $\bar{\tau}$, we must verify that the sum of labor income tax revenues not handed back as lump-sum transfers and the revenues from the capital tax and the payroll (social security) tax are sufficient for the government to finance social security benefits, interest on government debt, and the original small per-capita lump-sum transfer g totalling 1 percent of GDP in the benchmark 1 economy.

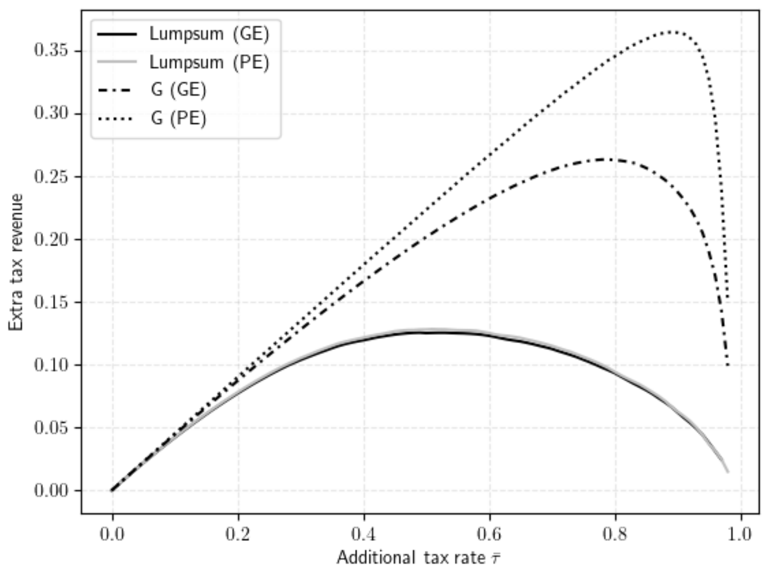


Figure 9: Laffer curves as functions of the extra tax $\bar{\tau}$. For curves labeled G, extra tax revenues are spent on a pure public good. For curves labeled lumpsum, extra revenues are distributed equally to all agents as lump-sum transfers. GE denotes general equilibrium, while PE denotes a partial equilibrium in which the interest rate is kept fixed at the value that prevails in the benchmark 1 economy.

cause a proportional reduction in the wage rate that would leave steady-state labor supply unchanged as substitution and income effects cancel. Other things equal, a similar cancellation of income and substitution effects would occur if the take-home wage rate were instead to be reduced by levying a proportional labor income tax (with all tax revenues being squandered) and hence, steady-state labor supply would remain unchanged. But capital formation rates are not equal across the two settings. While a multiplicative deterioration of the production function would leave all relevant equilibrium ratios unchanged including the fraction of agents' income devoted to investments that sustain the new steady-state capital stock, such invariance of equilibrium ratios would not prevail if the reduction of agents' take-home wage rate came about because of a proportional labor tax. In particular, since the production technology has not changed, the capital stock would need to stay unchanged in order to justify our temporary assumption of an unchanged before-tax wage rate upon which the cancellation of substitution and income effects hinges. But the capital stock would have to change because the investments required to sustain that unchanged capital stock constitute a larger share of agents' now depressed after-tax income. However, if we were to assume a small-open economy with an interest rate held constant at the economy's steady-state rate prior to the imposition of the proportional labor tax, outcomes would indeed be the same as if there had been a multiplicative deterioration of the production function. In the words of Prescott (2002, p. 7) above, "private consumption will fall, and the tax wedge will have little consequence for labor supply." Indeed, there would be no effect at all on labor supply because the capital flowing into the economy from abroad would completely make up for the shortfall in domestic savings at the unchanged interest rate.

The same logic explains the nearly linear dotted Laffer curve in Figure 9 along which the labor supply is largely constant (until other features in the present model set in, for example, social security benefits that are only imperfectly offset in the tax experiments under our auxiliary assumption that these benefits are reduced by the increment in the flat-rate tax).

Second, regarding the remarkable similarity of partial and general equilibrium Figure 9 Laffer curves with lump-sum rebates, the explanation is rather straightforward. The extra tax rate $\bar{\tau}$ now discourages supplying labor. As the tax rate increases, lower savings associated with workers' smaller incomes and lower demands for capital services by firms that now produce less output arrive hand in hand. Indeed, the nearly perfect overlap of the two Laffer curves (light and dark solid lines in Figure 9) indicate that capital flows are negligible in the small-open (a.k.a. partial equilibrium) economy with lump-sum rebate of the extra

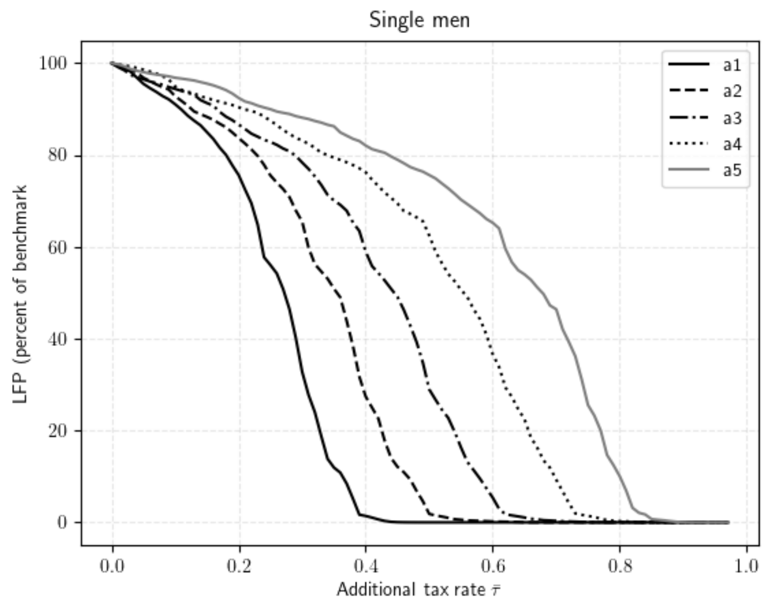


Figure 10: Labor force participation of single men by ability types along the lumpsum (GE) Laffer curve. The figure displays labor force participation (LFP) relative to benchmark 1 outcome as a function of the extra tax $\bar{\tau}$.

tax revenues.

To illustrate paltry labor supplies accompanying the dark solid Laffer curve, Figure 10 shows labor force participations of single men by ability types relative to benchmark 1 model outcomes as functions of the extra tax $\bar{\tau}$. We can also imagine how this tax and transfer program might undo the outcome of similarities observed in our Section 4.2 thought experiment that followed single men of lowest and highest abilities who shared the same realizations of productivity shocks and marital state. In that experiment, the two men's choices of reservation productivites and associated labor force participations were similar. In contrast, Figure 10 shows that single men of the lowest ability are the first to withdraw from labor market participation, while participation of the highest ability is more resilient to the distortions brought by the new tax and transfer scheme. Because the lump-sum transfer as a fraction of potential labor earnings differs so much across ability levels, so does the size of the associated income effect.

To emphasize how important it is whether a model fully implements time-averaging, we now compare outcomes across our benchmark 1 model and the original HKS model. We revisit two of HKS's policy settings: the U.S. tax system and a flat tax system. For each system we compute the peak of the Laffer curve (as a percent of benchmark 1 tax revenue) for the two alternative uses of new tax revenues: either handed back as a lump-sum transfer, or spent on the pure public good G. Table 3 brings out how big is the difference in outcomes between the two uses of tax revenues in our full-fledged time-averaging model and how much smaller they are in the original Holter et al. (2019, Table 7) model that implemented time-averaging only partially.

Table 3: The Peak of the Laffer Curve for Different Uses of Revenue

Benchmark 1 model			
	G	Lumpsum	Lumpsum/G
Flat Tax	195.5	152.9	78.2
U.S. Tax System	179.3	147.7	82.4
HKS model			
	G	Lumpsum	Lumpsum/G
Flat Tax	179.4	170.0	94.7
U.S. Tax System	167.1	159.3	95.3

The Table displays the peak of the Laffer curve (in percent of benchmark 1 tax revenues) for a flat tax and with the current U.S. tax system, under two different assumptions about the use of new tax revenues. "G" denotes that new tax revenues are used to finance pure public goods, while "Lumpsum" denotes that the revenues are handed back as lump-sum transfers to the households.

4.4 Benchmark 2 economy

We now study a modified version of the benchmark 1 economy in which social security rules have been changed to mimic a recent reform in the U.S. social security system. We call this our benchmark 2 model. The reformed system contains no implicit tax on working beyond age 65. Whether they work or not, at age 65 agents start to receive social security benefits according to formula (8).

Our having originally parameterized our benchmark 1 economy under an earlier social security system serves two purposes. First, we confirm that that system made most people choose to retire at or before age 65. Second, our approach helps us to discipline parameterizations of disutilities in our time-averaging model when retirement patterns among older workers were gradually changing as they did in the U.S. during the recent transition to a system with actuarially fair benefit calculations for those who chose to delay receiving social security benefits. When we disarm the corner solution in the benchmark 1 model by installing our assumed social security reform, our model offers predictions about equilibrium outcomes after the reform. For example, the dashed lines in Figures 4 and 5 show labor force participation by married and singles, respectively, after the social security reform.

4.5 Ex post-ex ante welfare measure

In addition to standard *ex ante* welfare measures, either unconditional or conditional on characteristics such as gender and ability type, we also construct what we call *ex post-ex ante* welfare measures that respond to concerns about collections of agents who, for some reason, find themselves in a particular bad situation at a given point in time. Of course, the particular individuals who comprise such a collection would vary over time. To recognize that, we propose a welfare measure that includes all agents who *ex post* find themselves in that state at a given age. We compute each such agent's experienced utility up and until that age and, as a continuation value, evaluate that agent's value function at his/her state at that age, then discount utilities back to the time when the person entered the economy. Next, by averaging over all those computed lifetime utilities in the subpopulation of agents who find themselves in that state at that age, we arrive at our *ex post-ex ante* welfare measure.

To gauge how inequality is related to marital state, let's put this *ex post-ex ante* welfare measure to use in our benchmark 2 economy. Specifically, we compute these welfare measures for each gender for someone who *ex post* experienced a particular marital state at a given age. Then we express welfare as consumption equivalents relative to the unconditional lifetime utility of an agent put into the economy as a 20-year old (the age at which a new cohort enters the economy) under the veil of complete ignorance about gender, ability type, marital state, and initial idiosyncratic productivity shock. Those *ex post-ex ante* welfare measures are reported in Figure 11.

The four categories of males and females who are either married or single in Figure 11 make up an entire cohort that we trace over time as the cohort ages until age 65, after which the marital state is constant. The figure reveals that marriage is better than singlehood. Starting at age 20, a small group of agents is already married; these people have the highest welfare as measured by a standard *ex ante* welfare measure conditional on being married for each gender (this coincides with our *ex post-ex ante* welfare measure at age 20). However, most people are single at age 20; since they constitute most of the population, their consumption equivalents are close to zero. For two reasons, singlehood becomes more and more disadvantageous as people age. Our *ex post-ex ante* welfare measure is both backward- and forward-looking. If someone is single at a ripe old age, the low marriage probabilities in Figure 1 make the future look bleak; and the recent past was most likely also spent in singlehood. This twofold misfortune makes the *ex post-ex ante* consumption equivalent for the state of singlehood fall. Low divorce probabilities in old age make things work in the opposite direction for married people; for them, *ex post-ex ante* welfare increases with age.[16]

[16] To check our algorithm, we can calculate the *ex post-ex ante* welfare for the *ex post* outcome of surviving until some age $x \leq 65$, i.e., we include the entire population since there is no mortality before age 65. Since

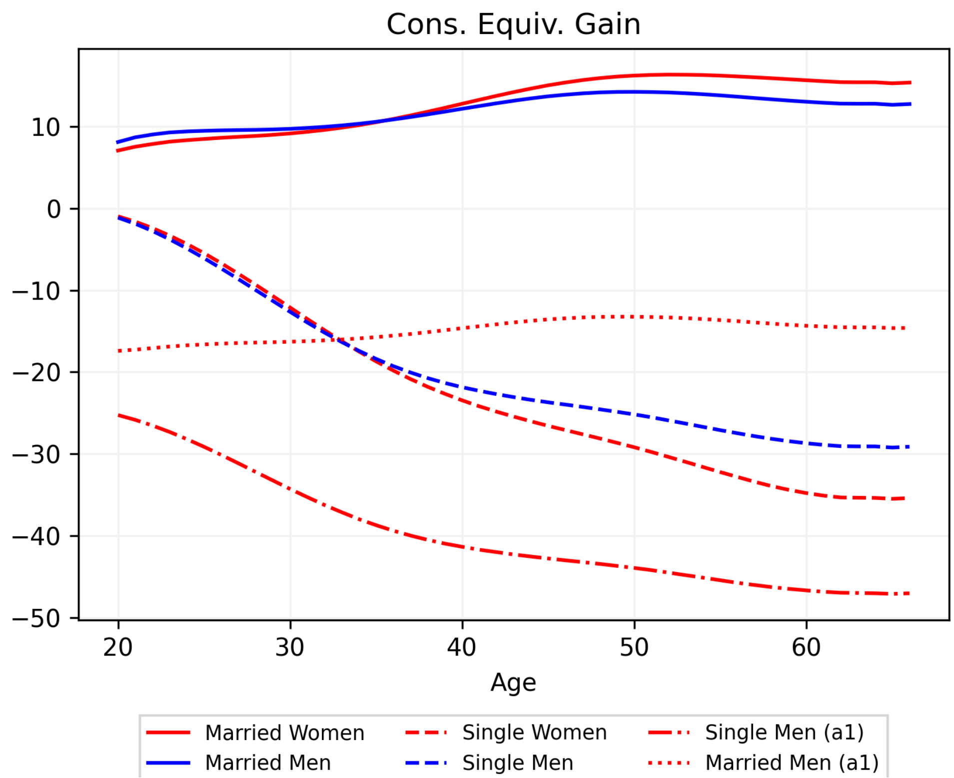


Figure 11: Ex post-ex ante welfare measures by marital state and gender as a function of age in the benchmark economy under social security reform. The dotted and dash-dotted lines break out males of the lowest ability as married and single, respectively. The consumption equivalents are relative to the unconditional lifetime utility of a 20-year old entering the economy under the veil of complete ignorance.

Figure 11 also depicts the *ex post-ex ante* welfare measures conditional on being a male of the lowest ability type. Evidently, ample heterogeneity that arises from differences in ability is embedded within measures based exclusively on gender and marital state.

5 Tax reforms

This section studies three classic reforms: a flat-rate tax, a negative income tax, and an earned income tax credit. We conduct our tax experiments in the benchmark 2 model. We use the allocation associated with benchmark 2 model as a reference point with respect to which we shall evaluate efficiency and distributional consequences of our tax experiments.

Our first reform is a flat-rate tax with zero deductions. Subsequent experiments perturb that reform by adding either deductions, a negative income tax, or an earned income tax credit. We'll also study some combinations of these perturbations.

Turning to our first experiment, relative to the benchmark 2 economy with its progressive tax system, a flat-rate tax with zero deductions brings substantial efficiency gains but helps high income households more than lower income households. Indeed, many households are worse off under the reform.

Our subsequent tax experiments aim to help those who lose from moving to a flat tax without unduly sacrificing efficiency. Figure 12 indicates how challenging this will be by showing marital-state-specific average tax rates at different household earnings under our benchmark 2 model's progressive tax system versus the constant tax under the flat-rate tax reform with zero deductions.[17] At low earnings, the labor income tax rate can be negative in the benchmark 2 economy with its progressive tax schedule; please inspect the average-tax-rate profile for married couples in Figure 12. (However, all workers also pay a payroll (social security) tax, so that according to our calibration in Table 1, 7.65 percentage points should be added to the average labor income tax rates in Figure 12.)

5.1 Flat-rate tax reform

For a given *deduction* of labor income exempt from taxation, expressed as a fraction of average income (see footnote 17), we compute the flat-rate tax that finances the same amount of pure public consumption good G as calibrated in the benchmark 1 economy and kept constant in the benchmark 2 economy, our present baseline economy.

our algorithm computes each agent's experienced utility until age x and uses his/her value function as a continuation value then averages across all agents, we should arrive at the unconditional expected utility of someone who is randomly dropped down as a 20-year old in the economy under the veil of complete ignorance.

[17] In our calibration of the progressive tax system in the benchmark 1 economy, the average income of all working individuals of age 64 or younger is normalized to equal 1.

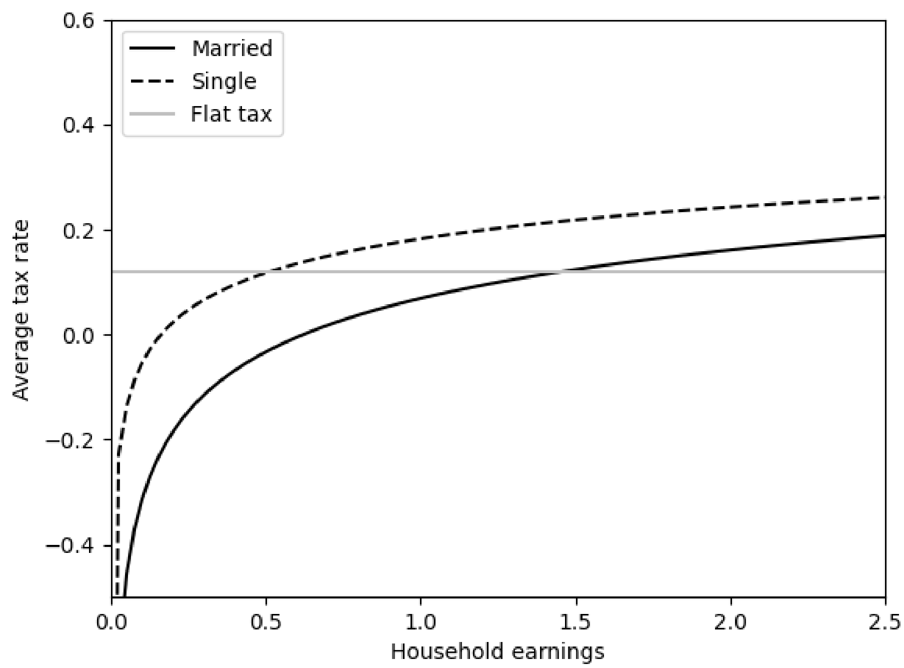


Figure 12: Average labor income tax rates under benchmark model progressive tax system and under a flat-rate tax reform with zero deductions, as functions of household earnings. The dark solid (dashed) line is the average tax rate for married couples (singles) under the progressive tax system; the light solid line is the flat-rate tax.

Descriptive statistics of flat-rate tax equilibria in Tables 4 and 5 reveal tradeoffs between efficiency and redistribution. As indicated by a standard unconditional *ex ante* measure of welfare, efficiency falls as the level of income exempt from taxation rises. While the lifetime utility of an agent put into the economy as a 20-year old under a veil of complete ignorance is higher under all three flat-tax reforms relative to the baseline economy, welfare *decreases* expressed in consumption equivalents are 2.88%, 2.74%, and 2.43% for flat-tax reforms with deductions of 0, 0.2, and 0.4, respectively.

To understand why unconditional *ex ante* welfare falls as the deduction increases, consider a flat-tax economy that is populated by agents all of whom work and have labor earnings that exceed the income level that is exempt from taxation. Such an economy would be isomorphic to another economy in which all labor earnings are subject to the flat tax and in which agents receive a lump-sum transfer from the government equal to the product of the flat tax and the level of income exempt from taxation in the first economy. Thus, the policy of the alternative economy is an example of the Prescott tax-and-transfer scheme analyzed above in subsection 4.3. In light of the isomorphism between the two economies, the first economy with a flat tax and a level of income exempt from taxation has the same distortions and welfare losses as the alternative economy under its Prescott tax-and-transfer scheme.

In our heterogeneous-agent model, average welfare gains of flat-tax reforms take into account mixed fortunes conditioned on genders and permanent abilities as well as *ex post* realizations of marital states, as shown in Table 5. Not surprisingly, individuals of high abilities gain most from replacing the progressive tax system in the baseline economy with a flat tax. Their gains are eroded when the level of income exempt from taxation is increased, while higher deductions improve welfare for almost all individuals of the lowest and the second lowest ability, an exception being single males of the second lowest ability. It is noteworthy that the only negative consumption equivalents of flat-tax reforms in Table 5 are for men and women of the lowest abilities. Furthermore, according to our *ex post-ex ante* welfare measures, those negative welfare outcomes relative to the baseline economy primarily befall married individuals of the lowest abilities. This reflects how marital-state-specific tax schedules lend an advantage to married couples in the form of a lower effective average tax rate, especially at the lowest earnings levels where the effective average tax rate can even be negative.

Table 5 reveals that the negative consumption equivalents of married individuals of the lowest ability persist as the deduction is raised as high as 0.4. In addition, efficiency losses are larger at higher deduction levels, as reflected by the above falling unconditional *ex ante* lifetime utility of a 20-year old under the veil of complete ignorance as well as the diminished positive *ex post-ex ante* consumption equivalents of higher ability individuals in Table 5. To

Table 4: Summary Statistics

	Baseline	Flat Tax (0 deduct.)	Flat Tax (0.2 deduct.)	Flat Tax (0.4 deduct.)	NIT 1	NIT 2	EITC 1	EITC 2	NIT with deduct.	EITC with deduct.
Capital	2.354	2.638	2.606	2.555	2.524	2.132	2.595	2.356	2.472	2.548
Total labor supply (all)	0.207	0.220	0.218	0.215	0.210	0.186	0.216	0.203	0.207	0.213
Labor supply, age 65+										
single men	0.03021	0.03887	0.03810	0.03695	0.03863	0.03096	0.03810	0.03196	0.03711	0.03710
married men	0.08764	0.09696	0.09569	0.09347	0.09379	0.06812	0.09328	0.07578	0.09052	0.09124
single women	0.03052	0.03531	0.03490	0.03427	0.03700	0.03890	0.03453	0.02904	0.03690	0.03363
married women	0.03368	0.02107	0.02233	0.02471	0.02864	0.06048	0.02398	0.04385	0.03186	0.02684
Labor supply before 65										
single men	0.276	0.290	0.287	0.284	0.272	0.233	0.284	0.273	0.268	0.281
married men	0.346	0.371	0.368	0.364	0.357	0.316	0.366	0.338	0.351	0.360
single women	0.245	0.254	0.251	0.249	0.228	0.179	0.245	0.231	0.225	0.241
married women	0.212	0.231	0.228	0.224	0.226	0.206	0.227	0.211	0.221	0.224
Average labor inc. tax rate										
all	15.97%	12.05%	12.44%	13.08%	13.72%	19.90%	12.62%	15.96%	14.42%	13.22%
married	15.05%	12.05%	12.47%	13.13%	13.66%	20.28%	12.76%	16.55%	14.47%	13.40%
single men	18.94%	12.05%	12.45%	13.16%	13.94%	21.56%	12.55%	16.68%	14.70%	13.26%
single women	16.14%	12.04%	12.01%	12.08%	13.29%	19.60%	11.82%	13.28%	13.41%	11.91%
Flat-rate tax	n.a.	12.07%	13.94%	16.81%	14.51%	25.70%	13.22%	20.58%	17.15%	14.69%
Interest rate	5.39%	5.07%	5.11%	5.17%	5.11%	5.50%	5.12%	5.43%	5.18%	5.18%
Ex-ante utility	0.000	2.878%	2.745%	2.426%	2.270%	-2.299%	2.626%	-0.065%	1.874%	2.272%

Table 5: Welfare Changes (Percentage Changes in Consumption Equivalent Units) in Flat Tax Reforms Compared to Benchmark 2 model as Baseline

	Ex ante 20-year olds	Ex post-ex ante 65-year olds married	Ex post-ex ante 65-year olds single
		Flat Tax with 0 Deduction	
Men (a1)	−1.129	−2.011	1.415
Men (a2)	1.020	0.179	3.486
Men (a3)	3.308	2.546	5.503
Men (a4)	5.682	4.985	7.643
Men (a5)	8.132	7.494	9.959
Women (a1)	−1.617	−1.603	−0.595
Women (a2)	0.312	0.318	1.143
Women (a3)	2.370	2.314	3.078
Women (a4)	4.531	4.475	4.987
Women (a5)	6.805	6.693	7.239
		Flat Tax with 0.2 Deduction	
Men (a1)	−0.641	−1.445	1.677
Men (a2)	1.111	0.335	3.393
Men (a3)	3.055	2.350	5.098
Men (a4)	5.131	4.477	6.967
Men (a5)	7.327	6.730	9.046
Women (a1)	−0.925	−0.911	0.127
Women (a2)	0.574	0.575	1.406
Women (a3)	2.258	2.197	2.964
Women (a4)	4.106	4.059	4.516
Women (a5)	6.118	6.000	6.499
		Flat Tax with 0.4 Deduction	
Men (a1)	−0.083	−0.748	1.845
Men (a2)	1.143	0.469	3.131
Men (a3)	2.593	1.970	4.382
Men (a4)	4.234	3.650	5.880
Men (a5)	6.055	5.514	7.611
Women (a1)	−0.250	−0.290	0.919
Women (a2)	0.796	0.780	1.669
Women (a3)	1.997	1.936	2.681
Women (a4)	3.402	3.343	3.786
Women (a5)	5.026	4.908	5.327

bring out the tension between redistribution and efficiency, we consider additional policy measures.

5.2 Negative income tax (NIT)

Milton Friedman cast the negative income tax as a modification of what was then the U.S. tax system. To distil essential ingredients of Friedman's proposal in our setting, we study it in the context of our flat-tax system with a zero deduction. We assume that workers are eligible for the negative income tax until age 65, after which they can receive social security benefits.

An individual who is not working receives a government benefit B that is reduced by a constant s times that individual's earned labor income. We want the effective tax rate $1-\tau-s$ on those labor earnings y to be less than 100%. (Friedman often set the maximum rate to be 50%.) In our flat-tax context, a beneficiary of a negative income tax faces a tax wedge equal to $(\tau+s)$, where τ is the flat tax that everyone pays and s is the additional tax rate paid on labor income until the agent has "lost" the entire benefit B, at which point the individual becomes a "regular" tax payer who owes the government the flat tax τ levied on his/her entire labor income. Thus, a household's net-of-tax labor income prior to age 65 is

$$D(y) = \max\Big\{(1-\tau-s)y + B, \quad (1-\tau)y\Big\}.$$

The threshold labor income at which a worker is no longer a beneficiary of the negative income tax is $\hat{y} = B/s$. Figure 13 portrays the mapping from a household's labor earnings y into its net-of-tax labor income $D(y)$, given a negative income tax policy indexed by the parameter pair (B, s). We have superimposed the mapping on the earnings distribution of married couples in which both spouses have lowest abilities and there is a flat tax and zero deduction. These individuals belong to groups with negative consumption equivalents in Table 5 whose welfare we want a negative income tax to increase.

To portray distributional consequences of a negative income tax, we report two such policy experiments denoted 'NIT 1' and 'NIT 2' in Tables 4 and 6. In the flat-rate tax economy with zero deductions, we introduce a marital-state-specific negative income tax. In the first experiment denoted 'NIT 1', a single person is entitled to $B_S = 0.05$ and a married couple $B_M = 0.1$, i.e., 5% and 10%, respectively, of average earnings of individuals in the baseline economy. Singles and married people face the same additional "implicit tax rate" $s = 0.1$ on labor earnings that is levied on labor income up to a threshold at which the benefit will be exhausted, i.e., $\hat{y}_S = B_S/s = 0.5$ and $\hat{y}_M = B_M/s = 1.0$. A comparison of the first panel of Table 6 to the first panel of Table 5 shows that males and females with lowest abilities are both better off as singles and as married in the steady state after the imposition

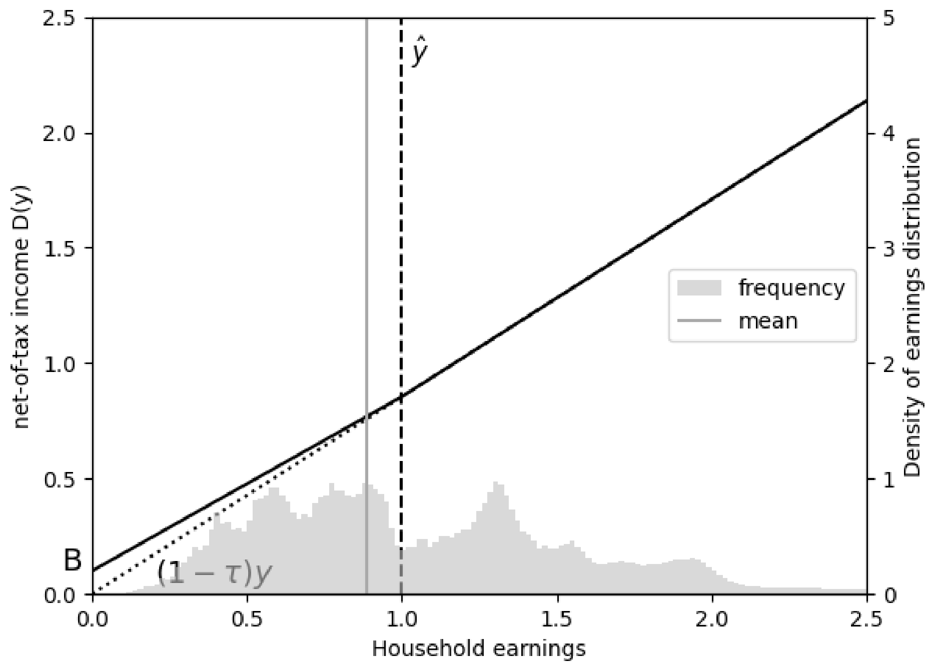


Figure 13: Mapping of labor earnings y into net-of-tax labor earnings $D(y)$ prior to age 65 (solid upper curve) and the earnings distribution of married couples with both spouses being of lowest abilities in benchmark 2 economy (shaded area) .

of 'NIT 1', as measured by the *ex post-ex ante* welfare measures for 65-year olds conditioned on marital states of being single and married, respectively. Welfares of single females in the three lowest ability levels improve, while everyone else loses (except for single males of the second lowest ability a small welfare improvement, who gain a small amount).

As a vivid illustration of limited gains to be expected from a tax reform, our next negative income tax experiment, denoted 'NIT 2', assumes that the benefit levels are twice those of NIT 1, so that a single person becomes entitled to $B_S = 0.1$ and a married couple $B_M = 0.2$, i.e., 10% and 20%, respectively, of average earnings of individuals in the baseline economy, while the "implicit tax rate" on labor earnings until benefits are exhausted is kept unchanged at $s = 0.1$. As compared to NIT 1, both married males and females of the lowest ability are better off as well as single females of the lowest ability. However, relative to the baseline economy, all married individuals are worse off and hence, the only positive consumption equivalents in the second panel of Table 6 are to be found among singles. As for single males, both the lowest and the highest ability levels have positive consumption equivalents, but for different reasons. Recall that single males of the highest ability had the highest consumption equivalent gain under a flat-rate tax reform with zero deductions, as shown in the first panel of Table 5. Evidently, the efficiency loss brought by NIT 2 cannot entirely erase that higher welfare as compared to the progressive tax system in the baseline economy. In contrast, single males of the lowest ability derive their positive consumption equivalent under NIT 2 from supplying less labor and choosing to avail themselves of the more generous benefit provided under the NIT 2 policy. As can be seen in Table 7, their labor supply is just 59.1% of what they supply in the baseline economy; only single females of the lowest ability curtail their labor supplies more, i.e., their labor supply is merely 39.9% of what they supply in the baseline economy.

Curtailment of labor supplies under the NIT 2 policy can be understood in terms of "implicit replacement rates." For those households who choose not to work, all single households or all married households can receive the same marital-state-specific benefit, i.e., B_S for singles and B_M for married couples. It follows that among idle households of the same marital state, those with lower abilities face higher "implicit replacement rates" relative to their earnings potentials. Furthermore, among households of the same marital state who choose to work, the households of lower abilities are advantaged because they will receive negative income tax benefits at higher income levels relative to their earnings potentials. Similar forces are active when we compare single females to single males. Thus, because of the assumed gender earnings differential and the difference in gender-specific earnings-experience profiles in Figure 3, females are more likely to earn labor incomes in the income interval that benefits from NIT. Likewise, for single females not working, the full NIT benefit

Table 6: Welfare Changes (Percentage Changes in Consumption Equivalent Units) in Negative Income Tax Reforms Compared to Benchmark 2 Economy as Baseline

	Ex ante 20-year olds	Ex post-ex ante 65-year olds married	Ex post-ex ante 65-year olds single
NIT (1): $\widehat{y}_S = 0.5$, $\widehat{y}_M = 1.0$, $B_S = 0.05$, $B_M = 0.1$, $s = 0.1$			
Men (a1)	−0.515	−1.574	2.569
Men (a2)	0.598	−0.418	3.535
Men (a3)	2.152	1.241	4.740
Men (a4)	4.050	3.223	6.424
Men (a5)	6.204	5.461	8.380
Women (a1)	0.034	−0.715	3.486
Women (a2)	0.671	0.052	3.229
Women (a3)	1.882	1.376	3.635
Women (a4)	3.446	3.037	4.633
Women (a5)	5.310	4.932	6.212
NIT (2): $\widehat{y}_S = 1.0$, $\widehat{y}_M = 2.0$, $B_S = 0.1$, $B_M = 0.2$, $s = 0.1$			
Men (a1)	−0.780	−1.264	0.176
Men (a2)	−2.800	−3.722	−0.196
Men (a3)	−3.452	−4.386	−0.710
Men (a4)	−3.250	−4.118	−0.609
Men (a5)	−2.380	−3.218	0.218
Women (a1)	1.112	−0.474	6.595
Women (a2)	−1.314	−2.551	2.875
Women (a3)	−2.558	−3.627	0.593
Women (a4)	−2.775	−3.613	−0.805
Women (a5)	−2.243	−3.009	−0.924

Table 7: Labor Supply

	Baseline	Flat Tax + 0 deduct.	Flat Tax + 0.2 deduct.	Flat Tax + 0.4 deduct.	NIT 1	NIT 2	EITC 1	EITC 2	NIT + deduct.	EITC + decuct.
Male	0.319	1.067	1.058	1.045	1.017	0.891	1.049	0.982	1.002	1.036
Single male	0.276	1.051	1.043	1.032	0.987	0.845	1.032	0.989	0.974	1.021
single male (a1)	0.268	1.050	1.037	1.025	0.938	0.591	1.013	0.953	0.918	0.996
single male (a2)	0.271	1.057	1.047	1.035	0.973	0.807	1.031	0.980	0.958	1.017
single male (a3)	0.277	1.050	1.041	1.029	0.986	0.879	1.030	0.990	0.973	1.020
single male (a4)	0.279	1.050	1.044	1.032	1.008	0.916	1.040	1.004	0.999	1.030
single male (a5)	0.281	1.050	1.044	1.036	1.022	0.954	1.045	1.016	1.014	1.039
Married male	0.346	1.074	1.066	1.052	1.032	0.913	1.058	0.979	1.016	1.043
married male (a1)	0.322	1.083	1.069	1.046	0.995	0.726	1.035	0.873	0.964	1.004
married male (a2)	0.335	1.076	1.066	1.047	1.020	0.872	1.052	0.944	1.000	1.032
married male (a3)	0.346	1.074	1.066	1.053	1.036	0.935	1.061	0.991	1.023	1.048
married male (a4)	0.356	1.072	1.066	1.055	1.045	0.973	1.065	1.018	1.036	1.056
married male (a5)	0.366	1.068	1.064	1.056	1.050	0.998	1.066	1.035	1.043	1.060
Female	0.225	1.069	1.056	1.040	1.011	0.872	1.042	0.973	0.991	1.027
Single female	0.245	1.037	1.026	1.016	0.931	0.731	1.000	0.942	0.917	0.985
single female (a1)	0.233	1.035	1.017	1.022	0.836	0.399	0.961	0.879	0.832	0.944
single female (a2)	0.239	1.037	1.022	1.012	0.909	0.625	0.980	0.914	0.889	0.960
single female (a3)	0.245	1.039	1.031	1.015	0.940	0.781	1.006	0.944	0.922	0.992
single female (a4)	0.252	1.033	1.023	1.014	0.960	0.846	1.012	0.968	0.947	1.001
single female (a5)	0.255	1.043	1.037	1.026	0.989	0.901	1.034	0.997	0.979	1.025
Married female	0.212	1.092	1.078	1.056	1.068	0.974	1.072	0.995	1.044	1.056
married female (a1)	0.146	1.133	1.097	1.043	1.054	0.812	1.046	0.838	0.994	0.997
married female (a2)	0.179	1.110	1.088	1.055	1.070	0.924	1.073	0.938	1.034	1.046
married female (a3)	0.212	1.093	1.080	1.059	1.075	0.984	1.079	1.004	1.052	1.065
married female (a4)	0.245	1.078	1.070	1.058	1.067	1.015	1.075	1.039	1.053	1.067
married female (a5)	0.277	1.070	1.065	1.058	1.061	1.034	1.071	1.060	1.052	1.066

'Baseline' column reports hours worked in the Baseline economy. All other columns report the ratio of the hours worked in the corresponding version of the model to the hours worked in the Baseline economy.

is so much higher as a replacement rate of labor income that could have been earned, when compared with single males, who gather much higher earnings in general.

To moderate the adverse consequences of incentives for poor people to work associated with a negative income tax, the earned income tax credit was invented. We turn to that policy next.

5.3 Earned Income Tax Credit (EITC)

The U.S. has an Earned Income Tax Credit (EITC) that aims to help working people who have low incomes. The EITC received depends on a recipient's labor earnings, marital state, and number of children. (It is also subject to an upper limit on capital income). Workers can receive the benefit beginning with their first dollar of labor earnings. Benefits rise linearly with labor earnings until they reach a maximum; then at higher earnings levels they phase out linearly. Unlike a negative income tax, an EITC recipient must work. In our model's version of an EITC, that work requirement is the only difference relative to our negative income tax reform. Specifically, we assume that only households with positive labor earnings are eligible to receive the EITC benefit, no matter how small.

The mechanics of our model are shaped by how the fixed disutility of working interacts the EITC to create incentives to supply labor at low income levels, just as the U.S. EITC does with its benefits that initially increase in labor earnings. The EITC benefit can motivate single individuals and married couples to incur a fixed disutility of working in order to receive the EITC. Having incurred that fixed disutility as what is now a sunk cost at the extensive margin, the worker chooses how much labor to supply while confronting the small variable disutility cost faced at an intensive margin.

To compare welfare outcomes under EITC and NIT, Table 8 reports on welfare outcomes under two EITC reforms, denoted 'EITC 1' and 'EITC 2', with policy parameters identical to those of NIT 1 and NIT 2, respectively. Comparing the two EITC reforms in Table 8 with the corresponding NIT reforms in Table 6 shows that married individuals of all abilities and genders are uniformly better off under EITC. In the case of EITC 2 versus NIT 2, EITC avoids the bad outcomes with NIT. The string of negative consumption equivalents for all married individuals under NIT 2 doesn't occur under EITC 2 for the lowest and the highest ability of each gender. Hence, there are still some categories of single individuals who are better off under the two NIT reforms than under the corresponding EITC reforms. Comparing NIT 1 with EITC 1, the singles who are better off under NIT are single males of the two lowest abilities and all single females except for the highest ability. Comparing NIT 2 and EITC 2, only single females of the three lowest abilities are better off under NIT 2, while everyone else is better off under EITC 2. The relatively poor performance of NIT compared to EITC is due to efficiency losses brought by providing NIT benefit to households

Table 8: Welfare Changes (Percentage Changes in Consumption Equivalent Units) in Earned Income Tax Credit Reforms Compared to Benchmark 2 Economy Baseline

	Ex ante 20-year olds	Ex post-ex ante 65-year olds married	Ex post-ex ante 65-year olds single
	EITC with parameters of NIT (1)		
Men (a1)	−0.454	−1.231	1.751
Men (a2)	0.955	0.144	3.328
Men (a3)	2.778	2.038	4.921
Men (a4)	4.874	4.178	6.850
Men (a5)	7.175	6.534	9.022
Women (a1)	−0.441	−0.276	0.814
Women (a2)	0.577	0.682	1.450
Women (a3)	2.049	1.993	2.774
Women (a4)	3.861	3.774	4.294
Women (a5)	5.941	5.779	6.306
	EITC with parameters of NIT (2)		
Men (a1)	0.311	0.277	0.402
Men (a2)	−0.635	−1.019	0.503
Men (a3)	−0.648	−1.167	0.906
Men (a4)	0.089	−0.488	1.844
Men (a5)	1.380	0.788	3.204
Women (a1)	1.213	1.228	2.848
Women (a2)	−0.158	−0.091	0.944
Women (a3)	−0.658	−0.654	−0.018
Women (a4)	−0.280	−0.364	0.006
Women (a5)	0.759	0.518	0.889

in which no one works. As an indication of costs brought by NIT relative to EITC, we use a standard unconditional *ex ante* welfare measure. Specifically, we compute the lifetime utility of a 20-year old under the veil of complete ignorance, expressed in consumption equivalents relative to the baseline economy. Those numbers for NIT 1 and NIT 2 are 2.27% and −2.30%, respectively, while corresponding numbers for EITC 1 and EITC 2 are 2.63% and −0.06%, respectively.

5.4 Combined policies

Beginning with the first panel of Table 5, our goal has been to find policies that lower welfare losses incurred by married individuals of the lowest ability associated with changing from the benchmark progressive tax system to a flat-rate tax. Studying outcomes from introducing deductions in the two lower panels of Table 5, NIT in Table 6, and EITC in Table 8 inspired us to combine deductions with either NIT or EITC, as denoted by 'NIT with deduction' and 'EITC with deduction', respectively, in Table 9. Specifically, we combine deduction 0.2 in the second panel of Table 5 with the NIT configuration in the first panel of Table 6 or with the EITC configuration in the first panel of Table 8, respectively. We are interested in complementary effects on the welfare distribution that might emerge in those combinations. In particular, while deductions are enjoyed by all workers, NIT and EITC are primarily advantageous to lower ability households.

The two experiments in Table 9 once again indicate that EITC is the preferable policy. In particular, married individuals of all abilities and genders are better off under EITC than under NIT. The only agents who are better off under NIT relative to EITC are single males of the two lowest abilities and all single females except for the highest ability. As discussed earlier, these groups reap welfare gains a by significantly reducing their labor supplies and choosing instead to live on the NIT benefits. Furthermore, the lifetime utility of a 20-year old under the veil of complete ignorance, expressed in consumption equivalents relative to the baseline economy, indicates a larger loss of efficiency under NIT as compared to EITC. As reported in Table 4, those *ex ante* welfare measures are 1.87% under 'NIT with deduction' and 2.27% under 'EITC with deduction'.

It is also enlightening to compate 'EITC with deduction' and the last panel of Table 5, i.e., a higher deduction 0.4 but neither NIT nor EITC. Agents who are better off under 'EITC with deduction [0.2]' are married males of the lowest ability, married females of the two lowest abilities, and single females of the lowest ability; single males of the highest ability are practically indifferent. Everyone else prefers a sole deduction of 0.4 in the last panel of Table 5. Turning to our *ex ante* welfare measures in Table 4, the larger redistribution under the former experiment has a price tag, but not that high. Specifically, the *ex ante* welfare of a 20-year old put into respective economy under the veil of complete ignorance, expressed in

Table 9: Welfare Changes (Percentage Changes in Consumption Equivalent Units) in NIT with Deduction and EITC with Deduction Reforms Compared to Benchmark 2 Economy as Baseline

	Ex ante 20-year olds	Ex post-ex ante 65-year olds married	Ex post-ex ante 65-year olds single
	NIT with Deduction		
Men (a1)	−0.009	−0.925	2.680
Men (a2)	0.524	−0.402	3.205
Men (a3)	1.605	0.762	3.996
Men (a4)	3.102	2.320	5.346
Men (a5)	4.914	4.212	6.983
Women (a1)	0.672	−0.117	4.219
Women (a2)	0.792	0.178	3.346
Women (a3)	1.511	1.003	3.250
Women (a4)	2.667	2.256	3.808
Women (a5)	4.181	3.797	5.004
	EITC with Deduction		
Men (a1)	−0.004	−0.635	1.799
Men (a2)	0.880	0.164	2.961
Men (a3)	2.269	1.596	4.224
Men (a4)	4.001	3.357	5.829
Men (a5)	5.995	5.399	7.725
Women (a1)	0.216	0.377	1.573
Women (a2)	0.713	0.827	1.578
Women (a3)	1.726	1.674	2.427
Women (a4)	3.157	3.072	3.529
Women (a5)	4.914	4.742	5.217

consumption equivalents relative to the baseline economy, are 2.43% under a sole deduction of 0.4 and, as mentioned earlier, 2.27% under 'EITC with deduction'.

To sum up, among our experiments, a combination a deduction 0.2 and the EITC configuration in the first panel of Table 8 attains the best outcomes for married of the lowest ability as well as single females of the lowest ability with relativley low loss of efficiency. (We ignore the extreme benefit configurations in the lower panels of Tables 6 and 8 with their large losses of efficiency.) Furthermore, this policy configuration stands out as having eradicated all negative consumption equivalents relative to the benchmark 2 economy, except for married males of the lowest ability. Married males of the lowest ability are an exception for the following reasons. First, the progressive tax system benefits married people of the lowest ability. Hence, we should have anticipated a challenge to undo the large negative consumption equivalents for married males and married females of the lowest ability in the first panel of Table 5, i.e., a flat-rate tax reform with zero deductions relative to the baseline economy with a progressive tax system. Then how did we succeed in erasing that negative consumption equivalent for married females of the lowest ability, but not for married males of the lowest ability? This comes down to their marriage prospectives. While both genders can benefit from marrying spouses of higher abilities, prospective gains along these lines are much lower for males because a female spouse of higher ability has earnings lower than males of the same ability, a consequence of the assumed gender earnings differential and the difference in gender-specific earnings-experience profiles in Figure 3.

6 Concluding Remarks

The large aggregate and individual labor supply elasticities in our quantitative heterogeneous agent, dynamic model come from responses at the extensive margin. Presumably, a reader of Saez (2002) would regard as plausible our finding that an EITC seems better than an NIT as an instrument for helping people in less advantageous labor market situations.[18]

Our decision to stay as close as possible to Holter et al.'s (2019) specification and parameterization has served us both as guide and constraint. The HKS model has guided us in assembling a quantitative general equilibrium model inhabited by heterogeneous individuals and couples within which we study how social security and tax systems affect workers' choices of career lengths. Likewise, we have retained HKS's representation of a married couple as a unitary household that awards each spouse the same utility of consumption that a single person would have gathered from consuming everything that the couple consumes. We have constrained ourselves not to investigate consequences of recalibrating our HKS benchmark model to have more persistent earnings shocks. Nevertheless, we think that this would be worthwhile, especially because of how persistence of shocks affects savings in a consumption-smoothing model like ours.[19]

To illustrate how expanding possibilities for HKS's agents to time average their labor supplies has affected outcomes, notice how Table 3 calls for revising HKS's conclusion that the "impact of tax progressivity on the peak of the Laffer curve is largely unaffected by the specification of what the government does with the extra revenue that is being generated with higher average tax rates" (Holter et al. 2019, p. 1348), which the table shows is not true in our full-fledged time-averaging version of HKS when the government returns tax revenues as lump-sum transfers. In our model, raising tax rates markedly suppresses the aggregate labor supply. To understand the source of these different outcomes, notice that, as (Holter et al. 2019, p. 1338) said, an implication of time averaging that "[the mathematical elasticity with respect to labor supply in their preference specification] cannot be interpreted as the *macro elasticity* of labor supply with respect to tax rates, see Keane & Rogerson (2012) for a detailed discussion".[20] But HKS had used a specification that by construction muted

[18]Saez (2002) solved optimal income tax problems in a one-period setting and found that when labor supply responses are mainly along an intensive margin, then a negative income tax is optimal, while when labor supply responses are mainly along an extensive margin, an earned income tax credit is optimal. In our time-averaging model, salient labor supply responses are at extensive margins.

[19]Richard Blundell pointed out that our calibrated income processes have much lower persistence than some that are often used in macro-labor papers about precautionary saving. See appendix A.5 for a critical assessment of our approach to this issue.

[20]Actually, Keane & Rogerson (2012) said little about the structure underlying time averaging. They said more about that in Section 4 of their NBER working paper (Keane & Rogerson 2011) upon which their publication (Keane & Rogerson 2012) cited by HKS is based. We recommend also reading our account of

Keane & Rogerson's distinction when they assumed an exogenous retirement age and set the Frisch elasticity of male labor supply to be low at the intensive margin. By activating time averaging of labor supplies only for females but not for males, HKS lowered the so-called *macro elasticity* in their model.

time averaging in Appendix A.1.

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A Appendix

A.1 From Employment Lotteries to Time-Averaging

This paper extends a twenty-year old aggregate labor supply paradigm shift from the Rogerson (1988) "employment lotteries" that Prescott (2005) said was an essential ingredient of his 2004 Nobel lecture to the "time averaging" theory that Prescott instead embraced when he updated his Nobel lecture (Prescott 2006*b*).[21] To appreciate the microeconomics that influenced the paradigm shift, recall how Prescott (2005, p. 385) used an aggregation theory of Rogerson (1988) that he said "is every bit as important as the one giving rise to the aggregate production function" to infer a high labor supply elasticity from aggregate employment fluctuations observed over business cycles. Rogerson obtained a high aggregate labor supply elasticity by combining (i) indivisible labor, with (ii) employment lotteries together with complete markets for insuring individual agents' consumption against the risk injected by those employment lotteries. When equilibrium employment-to-population ratios are less than one, those lotteries yield a large aggregate labor supply elasticity by convexifying individuals' labor supply choices. But micro-labor critics of Rogerson's aggregation theory saw no direct micro evidence for components (ii). Thus, Browning, Hansen & Heckman (1999, p. 602) wrote that the "employment allocation mechanism strains credibility and is at odds with the micro evidence on individual employment histories."

[21] See the added section "The Life Cycle and Labor Indivisibility" in Prescott (2006*b*). To learn more about Prescott's attitude about the significance of this paradigm shift, see his discussion (Prescott 2006*a*) of Ljungqvist & Sargent (2006).

Motivated partly by those criticisms, Ljungqvist & Sargent (2006) proposed and analyzed the time-averaging theory that was adopted by their discussant Prescott (2006*a*). Like the employment-lottery theory, it delivers a high aggregate labor supply elasticity although it discards Rogerson's employment lotteries and his assumption of complete consumption-insurance markets. The time-averaging theory replaces those components with a life-cycle model of labor supplies and intertemporal trades in non-state-contingent credit markets. Thus, in a continuous-time, non-stochastic life-cycle incomplete-market economy that retains Rogerson's indivisible labor component (i), Ljungqvist and Sargent deduced the same individual (expected) utilities, aggregate allocation and high aggregate labor supply elasticity that prevail in a Rogerson complete-market economy with employment lotteries.[22] In place of a representative *family* that chooses probabilities that individual family members work at each point in time, an individual is on his own and chooses a fraction of a lifetime to devote to work and how much to save and spend. A worker uses a credit market to smooth consumption across episodes of work and times of not working, perhaps called retirement. Among other things, Ljungqvist & Sargent (2006) showed that time averaging can replace lotteries and still deliver a high aggregate labor supply elasticity.[23] Prescott (2006*a*, p. 233) praised "the initiation of an important research program . . . to derive the implications of labor indivisibility for lifetime labor supply . . . a program that already has begun to bear fruit."[24]

Shifting to the time-averaging paradigm makes each individual worker responsible for allocating his time between work and leisure each period in light of his financial wealth and opportunities to borrow and lend. Relative to the employment-lottery model, it facilitates bringing to bear new evidence, including observations that concerned Browning et al. (1999). For example, Ljungqvist & Sargent (2014) studied how career lengths depend on shapes of the earnings profile, earnings shocks, taxes, and aspects of government financed retirement schemes.[25] Ljungqvist & Sargent (2008) investigated general equilibrium effects of taxation

[22]In terms of technical conditions, under time averaging, a high labor supply elasticity no longer merely requires an employment-to-population ratio less than one; instead it requires workers to be at interior solutions for their choices of career lengths.

[23]Independently, Chang & Kim (2006) discovered a high aggregate labor supply elasticity in simulations of a stochastic Bewley model with incomplete markets and indivisible labor. Their agents optimally alternate between periods of work and leisure (they "time average") to allocate consumption and leisure over their infinite lifespans.

[24]Prescott, Rogerson & Wallenius (2009) extended the Ljungqvist & Sargent (2006) framework by adding an intensive margin to the individual's labor supply decision. Given a constant wage over the life cycle, Prescott et al. affirmed Ljungqvist & Sargent's outcome that all adjustments in labor supply in response to taxation take place at the extensive margin. While Rogerson & Wallenius (2009) proceeded to activate the intensive margin by assuming exogenous life cycle variation in the wage – independent of a worker's labor market experience, the overarching conclusion remained that the extensive margin of labor supply is most critical for the magnitude of the aggregate labor supply elasticity.

[25]Under the auxiliary assumption that preferences are consistent with balanced growth, Ljungqvist &

and government supplied non-employment benefits in a life cycle model with human capital accumulation under both employment lotteries and time averaging, respectively. While many aggregate outcomes are similar in the two paradigms, there can be stark microeconomics differences in who works and who doesn't. These include dubious outcomes under employment lotteries that have workers with successful accumulation of human capital being destined never to retire.[26] When discussing Ljungqvist & Sargent (2008), Ríos-Rull (2008) advocated incomplete-market, heterogeneous-agent models and recommended abandoning representative-agent models, including those founded on the employment-lottery paradigm. Ríos-Rull conjectured that advantages brought by the time-averaging model be the "reason Rogerson (Rogerson & Wallenius, 2007 [working paper for 2009 article]) is now using OLG models without lotteries to address the employment question."

When Prescott had still relied on employment lotteries as an important pillar of his aggregate model, the magnitude of the aggregate labor supply elasticity separated Prescott (2002) (large) from Heckman (1993) (very small). The shift of macro-labor economists to the time-averaging life-cycle models fosters a potential reconciliation about different magnitudes of the aggregate labor supply elasticity inferred by Prescott (large) and Heckman (very small). It is noteworthy that before 2006 when Prescott and other real business cycle theorists had still relied on employment lotteries, a distinct life-cycle approach to modelling aggregate labor supply was also widespread. However, like HKS that work often imposed an exogenous retirement age. Examples date back at least to Auerbach & Kotlikoff's (1987) classic extension of the overlapping-generations structure of Diamond (1965) and Samuelson (1958) for quantitative policy analysis.[27] Heckman, Lochner & Taber (1998) also assumed

Sargent (2014) obtain stark outcomes under time averaging. For example, off corners, the more elastic are earnings to accumulated working time, the longer is a worker's career. This result suggests the possibility that it is a higher *slope* of the earnings-experience profile of high wage workers, and not the *level* of the wage *per se*, that explains why people with higher wages and higher educations are more likely to retire later in life. Evidence for such a relationship is provided by a study of married women's labor force participation by Eckstein & Wolpin (1989).

[26] Such incredible features of employment-lottery allocations were noted earlier, for example, when Ljungqvist & Sargent (2006, fn. 22) thanked "Richard Rogerson for alerting us to Grilli & Rogerson (1988) who also analyze human capital accumulation in a model with employment lotteries. The authors cite the story 'The Lottery in Babylon' by the surrealist Jorge Luis Borges, in which an all-encompassing lottery dictates all activities in a fictional society. The Borges story either arouses skepticism about the real-world relevance of the analysis or exemplifies that reality sometimes surpasses fiction."

[27] It is noteworthy that the coexistence of the employment-lottery paradigm and the life cycle approach at the time did not generate much of a discussion about their starkly different implications for the aggregate labor supply elasticity. Ljungqvist & Sargent (2008, fn. 21) even suggested that "[t]he current state of affairs in macroeconomics between the representative-agent framework and heterogeneous-agent models is best described as an 'harmonious' one. For example, Prescott (2006*b*) cites that the importance of total factor productivity shocks for business cycle fluctuations, as estimated in his representative agent model, is robust in the alternative heterogenous-agent models of Ríos-Rull (1994) and Krusell & Smith (1998)" where the overlapping generations of Ríos-Rull are subject to an exogenous retirement age and the infinitely-lived

an exogenous retirement age in their macro-labor analysis of schooling choices and Ben-Porath human capital accumulation in a life cycle model. But hard-wiring retirement ages disarms a force that can have big effects on labor supply elasticities. To unleash that force, retirement ages and career lengths must be endogenous. Letting individual workers choose career lengths opens ways to realize the vision of Browning, Hansen & Heckman (1999, p. 625): "Macroeconomic theory will be enriched by learning from . . . empirical research in microeconomics [and] microeconomics will be enriched by . . . dynamic general equilibrium theory."

A.2 Definition of a Stationary Recursive Competitive Equilibrium

We call an equilibrium of the growth adjusted economy a stationary equilibrium.[28] Let $\Phi^M(k^z, e^m, e^w, u^m, u^w, a^m, a^w, \Lambda^m, \Lambda^w, j)$ be the measure of married households with the corresponding characteristics and $\Phi^S(k^z, e, u, a, \iota, \Lambda, j)$ be the measure of single households. An equilibrium consists of a coherent collection of value functions and policy functions that satisfies the following conditions:

1. Value functions $V^M(\cdot)$ and $V^S(\cdot)$ and policy functions, $c^z(\cdot)$, $k^z(\cdot)$, $n^m(\cdot)$, $n^w(\cdot)$, $c(\cdot)$, $k(\cdot)$, and $n(\cdot)$ solve agents' optimization problems given factor prices, initial conditions, and beliefs about the distribution of prospective partners in the marriage market.

2. Markets clear:

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

$$L^z = \int \left(n^m w^{zm} + n^w w^{zf}\right) d\Phi^M + \int \left(n w^z\right) d\Phi^S$$

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

3. Factor prices satisfy:

$$w^z = (1-\alpha)\left(\frac{K^z}{L^z}\right)^\alpha$$

$$r = \alpha\left(\frac{K^z}{L^z}\right)^{\alpha-1} - \delta$$

agents of Krusell & Smith transition exogenously between work and nonwork.

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

4. The government budget balances:

$$g^z\left(2\int d\Phi^M + \int d\Phi^S\right) + G^z + (r-\mu)B^z + \left(\int_{j\geq 65}\Psi^z d\Phi^M + \int_{j\geq 65}\Psi^z d\Phi^S\right)$$
$$= \int\left(\tau_k r k^z + \tau_c c^z + \tau_l^M\left(\frac{n^m w^{mz} + n^w w^{wz}}{1+\tilde{\tau}_{ss}}\right)\right)d\Phi^M$$
$$+ \int\left(\tau_k r k^z + \tau_c c^z + \tau_l^S\left(\frac{n w^z}{1+\tilde{\tau}_{ss}}\right)\right)d\Phi^S$$
$$+ \frac{\tilde{\tau}_{ss}+\tau_{ss}}{1+\tilde{\tau}_{ss}}\left(\int (n^m w^{mz} + n^w w^{wz})d\Phi^M + \int n w^z d\Phi^S\right)$$

5. Single agents know the distribution of potential partners and form their expectations accordingly: $E[\Phi^S] = \Phi^S$

In computing an equilibrium, point 5 requires that we keep track of a vector with the pdf of singles at different ages. The vector contains the mass of singles of each gender with respect to asset holdings, labor market experience, fixed ability and stochastic productivity shock. Singles agents in the model use this vector to form expectations about future utility in the case of marriage. When computing equilibrium, we solve for agents' decision rules given the current pdf of singles, simulate the model and compare the simulated pdf of singles to last iteration's pdf. If this iteration's pdf and last iteration's pdf are not sufficiently close, we update our vector and solve the model again. We iterate this way until the pdf of singles has converged to a fixed point.

A.3 Tax Function

Given the tax function

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

we employ, the after tax income is defined as

$$ya = (1-\tau(y))y$$

and thus

$$\theta_0 y^{1-\theta_1} = (1-\tau(y))y$$

and thus

$$\begin{aligned}
1-\tau(y) &= \theta_0 y^{-\theta_1} \\
\tau(y) &= 1-\theta_0 y^{-\theta_1} \\
T(y) &= \tau(y)y = y-\theta_0 y^{1-\theta_1} \\
T'(y) &= 1-(1-\theta_1)\theta_0 y^{-\theta_1}
\end{aligned}$$

Thus the tax wedge for any two incomes (y_1, y_2) is given by

$$1-\frac{1-T'(y_2)}{1-T'(y_1)} = 1-\left(\frac{y_2}{y_1}\right)^{-\theta_1} = 1-\frac{1-\tau(y_2)}{1-\tau(y_1)} \quad (15)$$

and therefore independent of the scaling parameter θ_0.[29] Thus, by construction one can raise average taxes by lowering θ_0 and not change the progressivity of the tax code, since (as long as tax progressivity is defined by the tax wedges) the progressivity of the tax code[30] is uniquely determined by the parameter θ_1. Heathcote et al. (2017) estimate the parameter $\theta_1 = 0.18$ for all households. Above we let θ_1 vary by family type. When estimating the tax schedule, we normalized income in the data by dividing by average earnings. By setting the "technology level" parameter, we calibrated average earnings to equal one. In this way we have also normalized earnings by average earnings in what we call our benchmark 1 economy.

A.4 Modeling Choices and Comparison to Holter, Krueger and Stepanchuk (2019)

Our model builds on and extends the model in Holter et al. (2019) in several ways. One major extension is that our framework models an extensive margin of labor supply and accumulation of experience for men. Holter et al. (2019) only model an extensive margin of labor supply for women. Furthermore, we allow individuals to continue working beyond age 64, and we introduce an endogenous retirement decision. In our benchmark model, individuals above 64 who are working do not receive social security benefits but they can choose to retire, stop working and receive benefits.

There are some other minor differences between our framework and Holter et al. (2019).

[29] It should be noted that the last inequality only holds in the absence of additional lumpsum transfers.

[30] Note that

$$1-\tau(y) = \frac{1-T'(y)}{1-\theta_1} > 1-T'(y)$$

and thus as long as $\theta_1 \in (0,1)$ we have that

$$T'(y) > \tau(y)$$

and thus marginal tax rates are higher than average tax rates for all income levels.

Holter et al. (2019) have a distribution of fixed utility costs of working for single and married women. We only have one fixed utility cost of work but let it differ by gender and marital status. Furthermore, there are some differences in the fiscal system and in the choice of calibration targets. We use only one government budget constraint and let the social security benefits be an expense in the overall government budget. Holter et al. (2019) have a balanced social security budget in addition to a balanced government budget. We also provide a more realistic modeling of social security benefits and let them depend on gender, marital status, innate ability and years of experience. In Holter et al. (2019) everyone receives the same fixed social security benefit. Finally, we view innate ability in our model as a proxy for the level of education and we calibrate the correlation of spouses level of education. Holter et al. (2019) instead targeted the spousal correlation of wages.

A.5 Estimation of Shock Process and Returns to Experience From the PSID

We take the log of equation (3) and estimate a log(wage) equation using data from the non-poverty sample of the PSID 1968-1997. We use residuals from equation (3) to estimate (4). To control for selection into the labor market, we apply Heckman's 2-step selection model. For people who are working and for whom we observe wages, wages depend on years e of labor market experience, as well as dummies D for the years of observation:

$$log(w_{it}) = \phi_i(constant + D_t'\zeta + \gamma_1 e_{it} + \gamma_2 e_{it}^2 + \gamma_3 e_{it}^3 + u_{it}) \tag{16}$$

Apart from gender, labor market experience is the only observable determinant of wages in our model. Probabilities of participation depend on some demographic characteristics Z:

$$\Phi(participation) = \Phi(Z_{it}'\xi + \upsilon_{it}) \tag{17}$$

Included in Z are marital status, age, the number of children, years of schooling, time dummies, and an interaction term between years of schooling and age. To infer parameters, σ^{ι}, ρ^{ι} and $\sigma_{\alpha^{\iota}}$ we obtain the residuals u_{it} and estimate the following equation:

$$u_{it} = \alpha_i + \rho u_{it-1} + \epsilon_{it} \tag{18}$$

Estimated parameters appear found in Table 1. Figure 3 plots returns to experience profiles for men and women.

A.5.1 Comparisons with other specifications

Stochastic Wage Process: Our specification of the stochastic wage process, consisting as it does of a permanent fixed effect (drawn at birth) and an AR(1) process with yearly innovations, is not the only, or even the most common, one in the literature. It is perhaps have been more standard to have specified a fixed effect in addition to a persistent shock and a serially uncorrelated transitory shock.[31]:

$$\hat{u}_{i,t} = \alpha_i + \zeta_{i,t} + \epsilon_{i,t}$$

where $\epsilon_{i,t}$ is the transitory component and $\zeta_{i,t} = \rho\zeta_{i,t-1} + \eta_{i,t}$ is the persistent component[32]. Our specification thus assumes $\epsilon_{i,t} = 0$ in the above equation.

Our inferred values of ρ, 0.40 for men and 0.34 for women, are low when compared to some other researchers' estimates of AR(1) processes for wages that exclude a transitory shock. However, Lillard & Willis (1978) used the specification that we do and found similar results. They inferred $\rho \in [0.35, 0.406]$ depending on details of their specification. Estimates of the persistence parameter are known to be sensitive to whether a fixed effect is included, to whether one uses wage rates (as we do) or labor earnings, and to how many years one observes individuals' earnings. Chang & Kim (2006) estimated the AR(1) process that we have in equation (18), using wage rate data from the PSID and controlling for selection into the labor market, but without a fixed effect. They obtain ρ's of 0.809 for men and 0.735 for women. When they estimated a version of their equation without controlling for selection, they obtained slightly higher persistence parameters of 0.822 for men and 0.772 for women. If one instead estimates an AR(1) process for earnings without controlling for selection, the persistence parameter inferred increases further. Thus, Hugget (1996) obtained an earnings shock persistence of 0.96.

Brinca et al. (2021) estimate Equation (18) jointly for men and women in the PSID and obtain $\rho = 0.34$. They show that if one restricts the sample to individuals with at least 20 observations, ρ increases to 0.43[33]. One reason for this could be the so-called Nickel's bias, a negative bias in the standard fixed effect estimator when time series are short. Brinca et al.

[31] A widely used labor income process in macroeconomics is $\hat{u}_{i,t} = \zeta_{i,t} + \epsilon_{i,t}$; for example, see DeNardi et al. (1996), who include a serially uncorrelated transitory shock as well as fixed effects that are allowed to change over time

[32] More generally one could specify the age-dependent process

$$y_{i,a} = B'_{i,a} f_i + y^P_{i,a} + y^T_{i,a},$$

where $y^P_{i,a}$ is the persistent component, $B'_{i,a} f_i$ is the individual age-specific trend and $y^P_{i,a}$ is the transitory component, see Blundell (2014).

[33] This naturally leads to a reduction in the sample size

(2021) perform a Monte Carlo simulation to show that the bias with 30 years of data (the maximum length of our PSID data) is 12%.

Returns to Experience: Although we haven't found estimates directly comparable to our estimated experience profiles plotted in Figure 3, ours appear to align qualitatively with offer wage distributions across life-cycles that Blundell et al. (2024) infer from data from the current population survey. They find that women's wages have flatter age profiles than men's and that controlling for time effects, wages of college educated women peak at age 35 and are fairly flat thereafter (see Figure C3 in Blundell et al. (2024)). Wages for college educated men peak 10 years later at age 45. Our profiles are for years of experience, not age, so it is natural that they are steeper than the age profiles inferred by Blundell et al. (2024). Our experience profile for women peaks at 24 years of experience (age 44 if working all the time) and gives a 0.76 increase in log wages compared to someone with 0 experience. The experience profile for men is still increasing after 44 years of experience (the maximum in our model); 44 years of experience increases the log of male wages by 1.40.

A.6 Matching of Individuals in Marriage

Single households face an age-dependent probability, $M(j)$, of becoming married, whereas married households face an age-dependent probability, $D(j)$, of divorce. There is assortative matching in the marriage market, in the sense that there is a greater chance of marrying someone with similar ability, a fact that singles rationally foresee.

To implement assortative matching numerically, we introduce the match index, M_n, in the simulation stage of our computational algorithm. M_n is a convex combination of a random shock, $\varsigma \sim U[0,1]$ and permanent ability, a:

$$M_n = (1-\varphi)\varsigma + \varphi a \tag{19}$$

where $\varphi \in [0,1]$. Single men and women matched to get married in this period are sorted, within their gender, based on M_n, and assigned the partner of the opposite gender with the same rank. The parameter, φ, thus determines the degree of assortative matching, based on ability. If $\varphi = 0$, then matching is random and if $\varphi = 1$ spouses will have identical ability.

Singles have rational expectations with respect to potential partners. The matching function in Equation 19 implies conditional probabilities for marrying someone of ability, a', given an individual's own ability, a. Conditional on gender, age and permanent ability, we also keep track of the distribution of singles with respect to assets, labor market experience, female participation costs and idiosyncratic productivity shocks. A single individual can thus have a rational expectation about a potential partner with respect to these characteristics and the expectation will be conditional on the individual's own gender, age and permanent ability.

In section 3 we calibrate the parameter φ to match the correlation of the wages of married couples in the data. We model the normal distributions of abilities, $a \sim N(0, \sigma_a^{\iota 2})$, using Tauchen (1986)'s method and 5 discrete values of a, placed at $\{-1.5\sigma_a^\iota, -0.75\sigma_a^\iota, 0, 0.75\sigma_a^\iota, 1.5\sigma_a^\iota\}$. Given our calibrated value of φ we obtain the below matrix of marriage probabilities across ability levels:

$$\phi^{-\iota}(a|a^\iota;\varphi) = \begin{bmatrix} 0.502 & 0.312 & 0.152 & 0.033 & 0.000 \\ 0.184 & 0.420 & 0.280 & 0.098 & 0.018 \\ 0.066 & 0.213 & 0.441 & 0.215 & 0.066 \\ 0.018 & 0.097 & 0.279 & 0.424 & 0.183 \\ 0.001 & 0.034 & 0.151 & 0.312 & 0.502 \end{bmatrix}$$

A.7 Additional Tables and Figures

Table 10: Description of Tax Reforms

Tax Reform	Description
Flat Tax with 0.0 deduction	All labor income is taxed at a flat rate τ, net-of-tax labor income is $D(y) = (1-\tau)y$
Flat Tax with 0.2 deduction	Labor income above 0.1 for singles and 0.2 for married is taxed at a flat rate, net-of-tax labor income is $D(y) = \begin{cases} d_i + (1-\tau)(y-d_i) & \text{if } y > d_i \\ y & \text{otherwise} \end{cases}$ with $d_S = 0.1$ and $d_M = 0.2$
Flat Tax with 0.4 deduction	Similar to the previous case, but with $d_S = 0.2$ and $d_M = 0.4$
NIT 1	Net-of-tax labor income is $D(y) = \max\{(1-\tau-s)y + B_i, \quad (1-\tau)y\}$, with $B_S = 0.05$ for singles and $B_M = 0.1$ for married, and $s = 0.1$
NIT 2	Similar to NIT 1, but with $B_S = 0.1$, $B_M = 0.2$ and $s = 0.1$
EITC 1	Net-of-tax labor income is the same as under NIT 1 if working, 0 otherwise
EITC 2	Net-of-tax labor income is the same as under NIT 2 if working, 0 otherwise
NIT with Deduction	Net-of-tax labor income is $D(y) = \begin{cases} B_i - sy + y & \text{if } y \le \widehat{y}_i,\ y \le d_i \\ B_i - sy + (1-\tau)(y-d_i) + d_i & \text{if } y \le \widehat{y}_i,\ y > d_i \\ y & \text{if } y > \widehat{y}_i,\ y \le d_i \\ (1-\tau)(y-d_i) + d_i & \text{if } y > \widehat{y}_i,\ y > d_i \end{cases}$ with $d_S = 0.1$, $d_M = 0.2$, $s = 0.1$, $B_S = 0.05$, $B_M = 0.1$, $\widehat{y}_S = B_S/s$, $\widehat{y}_M = B_M/s$
EITC with Deduction	Net-of-tax labor income is the same as in 'NIT with deduction' if working, 0 othewise

d_S, d_M, B_S and B_M are fractions of average earnings in baseline 1 economy

Table 11: Summary Statistics (Before Pension Reform)

	Benchmark	Flat Tax (0 deduct.)	Flat Tax (0.2 deduct.)	Flat Tax (0.4 deduct.)	NIT 1	NIT 2	NIT with deduct.	EITC with deduct.	EITC with NIT 1	EITC with NIT 2
Capital	2.352	2.667	2.629	2.571	2.562	2.272	2.514	2.569	2.619	2.402
Total labor supply (all)	0.201	0.215	0.213	0.210	0.205	0.186	0.202	0.208	0.210	0.198
Labor supply, age 65+										
single men	0.00115	0.00365	0.00338	0.00290	0.00364	0.00253	0.00309	0.00308	0.00346	0.00233
married men	0.01143	0.01746	0.01664	0.01548	0.01595	0.01093	0.01489	0.01522	0.01631	0.01125
single women	0.00035	0.00169	0.00147	0.00119	0.00182	0.00144	0.00157	0.00129	0.00156	0.00064
married women	0.00117	0.00072	0.00072	0.00074	0.00088	0.00169	0.00083	0.00064	0.00065	0.00071
Labor supply before 65										
single men	0.282	0.297	0.294	0.291	0.279	0.248	0.276	0.289	0.292	0.280
married men	0.360	0.386	0.383	0.378	0.374	0.345	0.369	0.375	0.380	0.356
single women	0.251	0.261	0.258	0.256	0.237	0.196	0.233	0.248	0.252	0.238
married women	0.224	0.245	0.242	0.237	0.242	0.227	0.237	0.238	0.242	0.226
Average labor inc. tax rate										
all	16.59%	12.15%	12.61%	13.31%	13.63%	17.89%	14.31%	13.37%	12.73%	15.67%
married	15.83%	12.15%	12.67%	13.42%	13.67%	18.00%	14.43%	13.56%	12.86%	16.09%
single men	19.30%	12.14%	12.64%	13.42%	13.75%	18.21%	14.44%	13.41%	12.68%	15.89%
single women	16.32%	12.14%	12.19%	12.29%	13.14%	16.27%	13.20%	12.08%	11.98%	12.56%
Flat-rate tax	n.a.	12.12%	14.06%	17.03%	14.32%	21.78%	16.68%	16.56%	13.19%	19.55%
Interest rate	4.75%	4.40%	4.45%	4.52%	4.43%	4.69%	4.49%	4.51%	4.45%	4.73%
ex-ante utility	0.000%	3.057%	2.870%	2.522%	2.620%	0.328%	2.289%	2.464%	2.809%	0.860%

Table 12: Labor Supply (Before Pension Reform)

	Benchmark	Flat Tax + 0 deduct.	Flat Tax + 0.2 deduct.	Flat Tax + 0.4 deduct.	NIT 1	NIT 2	NIT + deduct.	EITC + deduct.	EITC + NIT 1	EITC + NIT 2
Male	0.330	1.065	1.057	1.044	1.021	0.932	1.009	1.035	1.048	0.989
Single male	0.282	1.053	1.043	1.032	0.989	0.880	0.979	1.023	1.033	0.991
single male (a1)	0.272	1.050	1.036	1.026	0.953	0.734	0.937	0.999	1.013	0.959
single male (a2)	0.278	1.047	1.038	1.026	0.968	0.845	0.955	1.013	1.024	0.983
single male (a3)	0.283	1.061	1.053	1.040	0.986	0.894	0.976	1.032	1.044	0.992
single male (a4)	0.287	1.053	1.039	1.028	1.010	0.928	1.002	1.025	1.036	1.000
single male (a5)	0.290	1.045	1.041	1.034	1.030	0.962	1.024	1.035	1.041	1.018
Married male	0.360	1.072	1.063	1.050	1.037	0.958	1.024	1.041	1.054	0.988
married male (a1)	0.336	1.081	1.067	1.045	1.006	0.861	0.982	1.006	1.034	0.910
married male (a2)	0.349	1.074	1.064	1.047	1.028	0.927	1.011	1.030	1.049	0.961
married male (a3)	0.361	1.071	1.063	1.050	1.041	0.968	1.029	1.045	1.057	0.995
married male (a4)	0.372	1.069	1.062	1.053	1.049	0.993	1.040	1.053	1.062	1.017
married male (a5)	0.382	1.066	1.061	1.053	1.052	1.011	1.045	1.057	1.063	1.032
Female	0.235	1.070	1.058	1.042	1.022	0.916	1.005	1.032	1.046	0.983
Single female	0.251	1.039	1.028	1.019	0.943	0.780	0.930	0.988	1.002	0.948
single female (a1)	0.237	1.039	1.020	1.021	0.854	0.511	0.851	0.942	0.964	0.887
single female (a2)	0.244	1.039	1.026	1.017	0.921	0.689	0.903	0.966	0.982	0.918
single female (a3)	0.252	1.033	1.026	1.014	0.944	0.821	0.928	0.986	1.001	0.950
single female (a4)	0.257	1.045	1.035	1.021	0.978	0.874	0.964	1.014	1.026	0.976
single female (a5)	0.264	1.038	1.033	1.028	0.999	0.918	0.990	1.023	1.030	0.997
Married female	0.224	1.092	1.079	1.059	1.078	1.011	1.058	1.062	1.077	1.007
married female (a1)	0.157	1.132	1.101	1.051	1.081	0.915	1.033	1.026	1.064	0.888
married female (a2)	0.191	1.109	1.089	1.056	1.084	0.986	1.055	1.058	1.081	0.967
married female (a3)	0.225	1.091	1.077	1.059	1.082	1.013	1.063	1.066	1.080	1.011
married female (a4)	0.258	1.079	1.072	1.061	1.073	1.038	1.062	1.068	1.077	1.042
married female (a5)	0.290	1.075	1.070	1.061	1.068	1.049	1.060	1.069	1.075	1.058

'Baseline' column reports hours worked in the Baseline economy. All other columns report the ratio of the hours worked in the corresponding version of the model to the hours worked in the Baseline economy.

Table 13: Welfare Changes (Percentage Changes in Consumption Equivalent Units) in Flat Tax Reforms Compared to Benchmark (Before Pension Reform)

	Ex ante 20-year olds	Ex post-ex ante 65-year olds married	Ex post-ex ante 65-year olds single
	Flat Tax with 0 Deduction		
Men (a1)	−0.834	−1.619	1.404
Men (a2)	1.234	0.498	3.345
Men (a3)	3.463	2.779	5.377
Men (a4)	5.768	5.178	7.512
Men (a5)	8.170	7.664	9.624
Women (a1)	−1.430	−1.437	−0.421
Women (a2)	0.490	0.519	1.117
Women (a3)	2.568	2.602	2.992
Women (a4)	4.752	4.733	5.099
Women (a5)	7.033	7.006	7.126
	Flat Tax with 0.2 Deduction		
Men (a1)	−0.417	−1.135	1.616
Men (a2)	1.271	0.596	3.214
Men (a3)	3.166	2.530	4.945
Men (a4)	5.182	4.654	6.745
Men (a5)	7.334	6.858	8.706
Women (a1)	−0.795	−0.820	0.264
Women (a2)	0.690	0.696	1.386
Women (a3)	2.395	2.417	2.844
Women (a4)	4.264	4.230	4.606
Women (a5)	6.288	6.257	6.380
	Flat Tax with 0.4 Deduction		
Men (a1)	0.060	−0.558	1.802
Men (a2)	1.254	0.673	2.938
Men (a3)	2.679	2.110	4.267
Men (a4)	4.281	3.810	5.668
Men (a5)	6.079	5.666	7.312
Women (a1)	−0.151	−0.189	0.902
Women (a2)	0.877	0.851	1.655
Women (a3)	2.102	2.118	2.551
Women (a4)	3.532	3.498	3.850
Women (a5)	5.174	5.101	5.354

Table 14: Welfare Changes (Percentage Changes in Consumption Equivalent Units) in Negative Income Tax Reforms Compared to Benchmark (Before Pension Reform)

	Ex ante 20-year olds	Ex post-ex ante 65-year olds married	Ex post-ex ante 65-year olds single
NIT (1): $\widehat{y}_S = 0.5$, $\widehat{y}_M = 1.0$, $B_S = 0.05$, $B_M = 0.1$, $s = 0.1$			
Men (a1)	−0.161	−1.194	2.807
Men (a2)	0.957	0.025	3.668
Men (a3)	2.523	1.727	4.769
Men (a4)	4.409	3.687	6.535
Men (a5)	6.557	5.923	8.433
Women (a1)	0.258	-0.466	3.568
Women (a2)	0.948	0.390	3.188
Women (a3)	2.223	1.793	3.663
Women (a4)	3.847	3.520	4.867
Women (a5)	5.767	5.506	6.416
NIT (2): $\widehat{y}_S = 1.0$, $\widehat{y}_M = 2.0$, $B_S = 0.1$, $B_M = 0.2$, $s = 0.1$			
Men (a1)	0.730	−0.318	3.480
Men (a2)	−0.450	−1.457	2.519
Men (a3)	−0.587	−1.472	1.997
Men (a4)	−0.076	−0.851	2.331
Men (a5)	1.033	0.330	3.230
Women (a1)	2.994	1.366	8.201
Women (a2)	0.857	−0.311	4.769
Women (a3)	−0.032	−0.975	2.851
Women (a4)	0.134	−0.556	2.051
Women (a5)	0.931	0.377	2.121

Table 15: Welfare Changes (Percentage Changes in Consumption Equivalent Units) in Negative Income Tax with Deduction and EITC Reforms Compared to Benchmark (Before Pension Reform)

	Ex ante 20-year olds	Ex post-ex ante 65-year olds married	Ex post-ex ante 65-year olds single
	NIT with Deduction		
Men (a1)	0.288	−0.644	2.989
Men (a2)	0.912	0.048	3.428
Men (a3)	2.061	1.312	4.166
Men (a4)	3.585	2.899	5.603
Men (a5)	5.419	4.816	7.205
Women (a1)	0.897	0.107	4.297
Women (a2)	1.092	0.527	3.345
Women (a3)	1.913	1.478	3.357
Women (a4)	3.165	2.836	4.161
Women (a5)	4.761	4.497	5.368
	EITC with Deduction		
Men (a1)	0.142	−0.465	1.842
Men (a2)	1.067	0.428	2.893
Men (a3)	2.462	1.850	4.193
Men (a4)	4.174	3.663	5.704
Men (a5)	6.147	5.682	7.516
Women (a1)	0.351	0.450	1.574
Women (a2)	0.867	0.974	1.545
Women (a3)	1.937	1.980	2.376
Women (a4)	3.415	3.350	3.727
Women (a5)	5.201	5.121	5.284

Table 16: Welfare Changes (Percentage Changes in Consumption Equivalent Units) in Negative Income Tax Reforms Compared to Baseline (Before Pension Reform)

	Ex ante 20-year olds	Ex post-ex ante 65-year olds married	Ex post-ex ante 65-year olds single
NIT (1): $\widehat{y}_S = 0.5$, $\widehat{y}_M = 1.0$, $B_S = 0.05$, $B_M = 0.1$, $s = 0.1$			
Men (a1)	-0.232	-0.937	1.755
Men (a2)	1.155	0.438	3.195
Men (a3)	2.951	2.284	4.833
Men (a4)	5.002	4.444	6.678
Men (a5)	7.266	6.757	8.737
Women (a1)	-0.286	-0.187	0.941
Women (a2)	0.737	0.858	1.366
Women (a3)	2.253	2.294	2.698
Women (a4)	4.098	4.039	4.429
Women (a5)	6.198	6.143	6.257
NIT (2): $\widehat{y}_S = 1.0$, $\widehat{y}_M = 2.0$, $B_S = 0.1$, $B_M = 0.2$, $s = 0.1$			
Men (a1)	0.688	0.478	1.333
Men (a2)	0.125	-0.296	1.363
Men (a3)	0.365	-0.104	1.743
Men (a4)	1.226	0.755	2.680
Men (a5)	2.594	2.129	4.033
Women (a1)	1.776	1.610	3.361
Women (a2)	0.606	0.633	1.496
Women (a3)	0.282	0.325	0.772
Women (a4)	0.817	0.794	1.067
Women (a5)	1.979	1.882	1.983