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Taxes on Lifetime Income: A Good Idea?

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Abstract

Household consumption and welfare are more strongly associated with lifetime income, but most countries base income taxes on current income and use progressive taxes to reduce inequality and provide social insurance. Is lifetime income a better tax base for a government seeking to provide social insurance and redistribution? To answer this question, we build a quantitative life-cycle model of heterogeneous households with endogenous labor supply and idiosyncratic wage risks, and calibrate it to the U.S. economy. We document that switching to a lifetime income tax leads to a more efficient distribution of hours worked over time and across states of the world. This benefit rises with tax progressivity under a lifetime income tax, whereas the opposite is true under an annual income tax. Consequently, the optimal lifetime income tax is more progressive and achieves larger ex-ante welfare for a cohort of households than the optimal annual income tax.

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1 Introduction

Most industrialized countries use a progressive income tax to redistribute resources from households with high market incomes to those with low market incomes, and to provide social insurance against idiosyncratic income fluctuations over time. Typically, the tax law bases this personal income tax solely on a household's income from the current year, independent of earnings in other years. However, a progressive income tax with rising marginal tax rates introduces distortions on labor supply, relative to the efficient allocation of labor, that might compromise the potential welfare benefits from social insurance and redistribution. An annual progressive income tax is especially detrimental in this regard when households experience strong deterministic or stochastic variations in their labor productivity. In that case, efficiency, at least with preferences that are separable between consumption and labor/leisure, would dictate strong variation of labor supply over the life cycle. However, with a progressive tax system this variation in labor supply drives up the average tax rate for these households, relative to similar households that face more stable productivity profiles.

As already argued by Vickrey (1939), a tax on lifetime income naturally avoids such distortions and therefore may prove to be a more efficient tool for income redistribution and insurance. In the simplest case when there is no income risk and households can transfer resources freely across time through asset markets, lifetime income is a sufficient statistic for household welfare, and therefore, a perfect target for welfare redistribution. However, households are subject to income shocks over life cycle, may face potentially binding borrowing constraints and must make labor supply and consumption decisions before the uncertainty about their lifetime income is fully resolved. Realized lifetime income is then no longer a perfect measure of household welfare, and whether a lifetime income tax is still preferable under these circumstances is a quantitative question.

In this paper, we explore the positive and welfare properties of a lifetime income tax (LIT) system and contrast it with the status quo in which income taxes are based on annual earnings (AIT). First, we use a two-period model with endogenous labor supply and income risk in the second period to clarify the main trade-off between the two tax systems. We demonstrate theoretically that a lifetime income tax is more conducive to an efficient allocation of labor, both across time and across states of the world, but that it compromises the provision of consumption insurance later in the life cycle, relative to a tax on period income.

To quantify this trade-off, we then construct a quantitative incomplete-markets life-cycle model featuring households that are ex ante heterogeneous with respect to permanent labor productivity and that are exposed to uninsurable idiosyncratic labor productivity shocks, inducing further ex-post heterogeneity. They make consumption-savings and labor supply decisions. The income tax policy is encoded in a nonlinear tax function that links household pre-tax earnings to their tax liability.[1] Under an annual income tax, both pre-tax earnings and tax liabilities pertain to the current year. In contrast, a lifetime income tax bases total tax liabilities on (discounted) lifetime earnings. We implement the lifetime income tax such that in every period households pay the increment in their lifetime tax liability resulting from the increase in their accumulated lifetime income due to their current earnings.[2]

The production side of our model is standard and consists of perfectly competitive firms with a constant-return-to-scale technology that combine labor and capital to produce a final good that can be used for consumption and capital investment. In our benchmark analysis we assume a linear production technology, and thus factor prices are unaffected by tax reforms. This assumption (which renders the analysis effectively a partial equilibrium analysis) is relaxed in the robustness analysis, where we consider an alternative scenario in which factor prices are fully endogenous and determined by domestic market clearing.

The government, in addition to the labor income tax, the focus of our analysis, also collects revenues through consumption-, capital income-, and payroll taxes to fund expenditures on public goods, retirement benefits, and interest payments on government debt. The model is calibrated to mirror the U.S. economy between 1999 and 2017.

Using our quantitative model, we quantify the welfare gains from switching the tax base to lifetime income. We measure welfare as expected lifetime utility of a cohort born into the stationary equilibrium of the model. To insure comparability across tax systems we ensure that all systems collect the same present discounted value of taxes from a newborn cohort.[3]

[1]The nonlinear income tax in our paper applies only to labor income and captures tax credits and government transfers as negative taxes. Although the income tax code in practice covers certain forms of capital income as well, this type of income is often taxed separately from labor income, and various forms of capital income are subject to complex and heterogeneous tax rules. Therefore, following much of the literature on progressive income taxation we model the capital income tax as a separate and flat tax.

[2]When implementing the LIT, the government chooses a discount rate for calculating household lifetime earnings and tax liability; this rate is a policy parameter. We find that using a zero discount rate allows for larger welfare gains from lifetime income tax than using the positive market interest rate. A lower discount rate places greater weights on earnings later in life, resulting in a rising life-cycle profile of average tax rate. This choice has the additional advantage of removing age as argument from the tax formula.

There are two additional (but unmodeled) practical advantages of our specific implementation of lifetime income tax. First, as long as the marginal tax rate remains below 100%, households can meet their tax obligations with their current earnings in each period. This is naturally satisfied with annual income tax, but may not hold in alternative implementations of a lifetime income tax. Second, the government continues to collect taxes and settle accounts with each household on an annual basis, preventing the accumulation of tax liabilities over multiple years.

[3]That is, we deliberately abstract from intergenerational redistribution across different cohorts that a tax reform might entail in a stationary equilibrium. Insisting that all polices satisfy the same within-cohort government budget constraint insures that the net tax revenue collected from each cohort remains unchanged. If one further assumes that a policy reform is only applicable to new households and that factor prices are constant as we do in the benchmark analysis, then the transition (for newborn generations) is immediate and tax reforms showing welfare gains for newborn cohorts are in fact Pareto-improving: all current generations

As in the simple model, both the annual and lifetime income taxes present policymakers with the trade-off between seeking to implement an efficient allocation of labor over time and across states on one hand, and the provision of social consumption insurance (against idiosyncratic risk) and redistribution (between different productivity types) on the other hand. With incomplete financial markets and in the absence of state-contingent lump-sum taxes, the efficiency and the insurance/redistribution motives cannot be fully separated in a competitive equilibrium. The desire to provide insurance and redistribution calls for a progressive income tax system. However, progressive income taxation entails rising marginal tax rates as earnings increase, which discourages labor supply in periods of high labor productivity and thus reduces aggregate labor efficiency (defined in this paper as the ratio between total earnings and total hours worked). Furthermore, households can still achieve partial self-insurance through precautionary savings and adjustments in hours worked, and an expansion of public insurance may partially crowd out such private self-insurance.

As our simple model suggests theoretically, the quantitative analysis confirms that a lifetime income tax renders the labor supply distortions less severe, but at the expense of less effective social insurance and redistribution from a tax system with a given degree of tax progressivity. Because marginal tax rates are less sensitive to earnings fluctuations under a lifetime income tax, household labor supply decisions are less distorted over time and across idiosyncratic wage states, leading to a more efficient distribution of hours worked in the economy. Consequently, we find that switching from the status quo annual income tax to a lifetime income tax with the same progressivity raises aggregate labor efficiency by 1.14% and induces welfare gains equivalent to 0.44% of household lifetime consumption.[4]

Furthermore, we find that aggregate labor efficiency increases with tax progressivity (starting from the status quo) under a lifetime income tax, whereas it falls with an annual income tax. This is the result of two opposing forces. First, a more progressive tax system widens the gap in the marginal tax rate between high- and low-wage households, and thus depresses the incentives of high-wage households to work relative to low-wage households, in turn shifting the hours distribution away from high-productivity households, thereby reducing aggregate labor efficiency.[5] This adverse effect is weaker, however, under a lifetime income tax since marginal tax rates are less responsive to current earnings under such a system. Second, however, a more progressive income tax system also reduces the dispersion of consumption (across ex-ante different people and across different states of the world ex

already alive are unaffected, and new generations immediately enjoy the welfare gains from the reform.

[4]We employ the two-parameter tax function from Bénabou (2002) and Heathcote et al. (2017) in which tax progressivity is measured as one minus the elasticity of after-tax earnings with respect to pre-tax earnings.

[5]This argument applies both to ex-ante different (with respect to their labor productivity) households as well as to the same household in different idiosyncratic labor productivity states.

post), and the relatively lower consumption of high-wage individuals induces them to work harder, thereby enhancing aggregate labor efficiency. Under a lifetime income tax this second effect dominates and aggregate labor efficiency actually rises with tax progressivity (up to a point), whereas it falls under annual income taxation.

The same intuition also carries over to our analysis of the optimal degree of tax progressivity. Due to the additional labor efficiency gains from a more progressive lifetime income tax, the optimal lifetime income tax is more progressive and attains larger welfare gains than the optimal annual income tax. Switching from the status quo policy to the optimal lifetime income tax boosts labor efficiency by 1.55% and improves social welfare by 1.60% of lifetime consumption. Consistent with our earlier discussion, the optimal lifetime income tax induces a more efficient distribution of hours worked, and therefore leads to greater hours- and earnings inequality. Nevertheless, this tax system reduces *consumption* inequality substantially. In comparison, the optimal annual income tax reduces labor efficiency by 0.40% and achieves a welfare gain equivalent to 0.63% of lifetime consumption relative to the current annual income tax with status quo progressivity.

Finally, accounting for general equilibrium effects from the tax reforms leads to significantly more progressive optimal policies and larger welfare gains for both annual and lifetime income taxes. However, the welfare ranking between the lifetime income tax and annual income tax remains unchanged in that the lifetime tax leads to maximum welfare gains that are about 1% (of lifetime consumption) higher than the annual tax (8.87% vs. 7.85%).

1.1 Related Literature

The idea of lifetime income taxes dates back to Vickrey (1939). In the context of progressive income taxation, and for the purpose of avoiding excessive taxes on fluctuating incomes relative to stable incomes and for preventing tax evasion via income shifting between years, Vickrey proposed an income tax system based on the average income of past years; our implementation of the lifetime income tax builds on this idea. Although Vickrey's proposal is a century old and has intuitive appeal, the literature on model-based quantitative analyses of progressive lifetime income taxation is sparse. Our paper seeks to partially fill this gap.

Our paper contributes to two broad literatures. First, a large body of work studies optimal nonlinear income tax in quantitative dynamic models with heterogeneous households in the Ramsey tradition in which a government can fully commit to a future path of taxes and is restricted to "simple" progressive tax functions. Key contributions include Bénabou (2002), Conesa and Krueger (2006), Conesa et al. (2009), Heathcote et al. (2017), and more recently Boar and Midrigan (2022), Dyrda and Pedroni (2022), and Holter et al. (2023). This literature confines income tax policy to be based on annual income; our analysis uncovers that switching to a lifetime income tax holds the potential for significant welfare gains.

Second, the new dynamic public finance approach, developed as an alternative to the optimal Ramsey taxation literature solves for the constrained efficient allocation in economies subject to informational and enforcement frictions, and then discusses the decentralization of these allocations with judiciously chosen tax systems, see, e.g., Golosov et al. (2003), Kocherlakota (2005), Albanesi and Sleet (2006), Battaglini and Coate (2008), Farhi and Werning (2007), Werning (2007), Golosov et al. (2016), and Farhi and Werning (2013). Typically, this decentralization requires a complex tax system that depends on the entire history of past incomes.[6] One actual part of the current U.S. fiscal constitution, as in many other countries, that features this type of history dependence is social security, although it differs from a lifetime income tax along several dimensions.[7] Consequently, our paper is related to the literature that studies the redistributive and incentive effects of social security. For example, Grochulski and Kocherlakota (2010) argue that it is possible to implement a socially optimal allocation using a social security system in which taxes/transfers are history-dependent only at retirement. Recent quantitative studies on the optimal progressivity of social security system with parameterized benefit function include Fehr et al. (2013) and Ábrahám et al. (2024). These papers examine a pay-as-you-go social security system, and intergenerational transfers play a crucial role in shaping their results. In contrast, we focus on comparing the performance of annual and lifetime income taxes in providing insurance and redistribution within each generation by imposing a within-cohort government budget constraint.[8]

The two papers most closely related to our study of a lifetime income tax are Huggett and Parra (2010) and Kapička (2020). The main focus of Huggett and Parra (2010) is a reform of the U.S. social security system. In the reform most relevant for our paper, the authors replace, in a partial equilibrium analysis, the entire income tax and social security system with an optimal tax on lifetime earnings. We instead focus on a reform of the income tax

[6] Starting from the observation that such history-dependent tax systems are often perceived as overly complex for practical implementation, a literature explores simplified alternatives retaining some key features of the full-history-dependent optimal tax policy, for example, by allowing taxes to depend on age, as studied by Kremer (2001), Erosa and Gervais (2002), Garriga (2001), Blomquist and Micheletto (2008), and more recently Heathcote et al. (2020). Weinzierl (2011) finds that introducing such age dependence into the income tax system can lead to substantial welfare gains. In contrast, our paper explores a different dimension of tax reforms and considers how much welfare improvement can be achieved by introducing a simplified form of history dependence, i.e., allowing taxes to be conditioned on accumulated lifetime earnings.

[7] For example, the actual U.S. system includes caps on taxable earnings, implicit annuitization of the benefits, the presence of spousal and survivors benefits, to name a few.

[8] Implementing a lifetime income tax through social security presents additional challenges. For instance, since all taxes and transfers would be settled at retirement, households receiving transfers might need to borrow substantially early in life, and binding borrowing constraints may raise problems in this regard. Conversely, households with substantial tax liabilities might lack sufficient funds to pay these liabilities at retirement.

system, keeping the social security system unchanged. They find that the introduction of a lifetime income tax leads to a small welfare loss, in the quantitative version of their model with persistent and transitory wage shocks. As Huggett and Parra (2010) acknowledge, however, their model understates wage and earnings inequality in the data.[9] This could lead to an understatement of the labor efficiency gains from a lifetime income tax that we stress in our paper. Our quantitative model aligns closely with the empirically observed life-cycle profiles of wage and earnings dispersion[10] and therefore has a larger scope for the lifetime income tax reform to generate labor efficiency- and thus welfare gains. Our quantitative results confirm that this potential indeed materializes.

Second, in his theoretical study of the optimal history dependence of income taxes, Kapička (2020) allows taxes to depend on a geometrically weighted average of past incomes. He then studies the optimal weight on past incomes, in the context of the analytically tractable incomplete markets economy of Heathcote et al. (2014). To permit closed-form solutions, the framework abstracts from life cycle considerations and household savings decisions that are at the heart of our model. Furthermore, in his model optimal hours worked are constant over time and across labor productivity states. Therefore a change in tax policy only affects the level of labor supply, but cannot induce a more efficient distribution over the life cycle and across idiosyncratic states, the main source of welfare gains from a lifetime income tax in our model. In the assumed absence of individual savings to smooth idiosyncratic shocks, a history-dependent income tax might be a useful tool to help households smooth consumption over time. Thus, Kapička (2020) finds that the optimal history-dependent tax is more progressive in current income but regressive in past incomes, i.e., a temporary increase in current income is taxed more heavily today but raises future after-tax income, in the same way private savings (if permitted) would respond to such shocks.[11]

Section 2 presents an analytically tractable two-period model to explain the key benefits and costs of a progressive lifetime income tax, relative to a progressive annual income tax. Section 3 sets up the quantitative model, and Section 4 discusses its calibration. Section 5 investigates the welfare and economic implications of implementing a lifetime income tax. Section 6 conducts robustness analysis, and Section 7 concludes.

[9] They present inequality measures from their full model in Figure 4 of the original paper.

[10] The key differences between the two frameworks giving rise to this difference is that the variance of the fixed effect of labor productivity in our model is calibrated to capture variation in wages due to *both* unobservable and observable factors and we also permit preference heterogeneity in the disutility of labor (as in Bick et al. (2024) or Urquizo (2025)) which generates additional dispersion in hours worked.

[11] Further differences include the fact that in Kapička (2020) current income taxes depend on a weighted geometric average of current and past incomes, whereas our lifetime income tax is equivalent to using an arithmetic average. Finally, his paper permits the tax system to be age-dependent; the age-dependent tax level parameters are chosen optimally and are functions of the history-dependent tax parameters.

2 The Two-Period Model

2.1 Environment

Consider a two-period life-cycle model of households in partial equilibrium with exogenous interest rate and wages. There is a continuum of measure 1 of ex ante identical households that work and consume in each period, and they can also save or borrow at the risk-free interest rate r in the first period. In the first period, all households earn wage w_1, but the state in the second period $s \in S$ is uncertain, which affects the second-period wage $w_2(s)$. Let f and F denote the probability density function (pdf) and cumulative density function (cdf) for the state s. Shocks are idiosyncratic, and we assume that a law of large numbers applies, so that f and F are also the pdf's and cdf's of the population distributions across households in the second period. Households value consumption and dislike labor according to the same period utility function we will assume in the quantitative part of the paper:

$$U(c, l) = \frac{c^{1-\sigma} - 1}{1 - \sigma} - \psi \frac{l^{1+\frac{1}{\eta}}}{1 + \frac{1}{\eta}}. \tag{1}$$

The government levies (potentially negative) taxes; for simplicity we assume that the government does not spend on goods and services. As private households, the government has access to an intertemporal technology that turns one unit of consumption today into one unit of consumption tomorrow. That is, the real interest in our model is equal to zero both for private agents and the government. Furthermore, individuals (and therefore the benevolent government) do not discount the future: the time discount rate is zero as well.

Let $j = 1, 2$ denote household age, c_j, l_j, and a denote household consumption, labor supply, and savings, respectively. The household's problem is then:

$$\max_{\{c_1, l_1, a, [c_2(s), l_2(s)]_{s \in S}\}} U(c_1, l_1) + \mathbf{E}\{U(c_2(s), l_2(s))\} \qquad \text{s.t.}$$

$$c_1 + a = w_1 l_1 - T(w_1 l_1), \quad \text{and} \quad c_2(s) = a + w_2(s) l_2(s) - \widetilde{T}(w_2(s) l_2(s), w_1 l_1), \ \forall s \in S.$$

Expectations $\mathbf{E}$ are taken with respect to s, and T and $\widetilde{T}$ are tax functions in the first and second periods. Tax liabilities in the second period can depend on first-period earnings.

2.2 Tax Systems

Under an annual income tax (AIT), the tax function in the second period satisfies:

$$\widetilde{T}(w_2 l_2, w_1 l_1) = T(w_2 l_2),$$

so the tax function is the same in each period and depends only on current-period earnings. The expected present value of taxes paid over the household lifetime is given by

$$T(w_1 l_1) + \mathbf{E}\{T(w_2(s) l_2(s))\}. \tag{2}$$

In contrast, when the government levies a lifetime income tax (LIT), the second period tax bill is given by

$$\widetilde{T}(w_2 l_2, w_1 l_1) = T(w_1 l_1 + w_2 l_2) - T(w_1 l_1),$$

with expected present discounted value

$$T(w_1 l_1) + \mathbf{E}\{\widetilde{T}(w_2(s) l_2(s), w_1 l_1)\} = \mathbf{E}\{T(w_1 l_1 + w_2(s) l_2(s))\}, \tag{3}$$

such that total lifetime tax liabilities are only a function of lifetime earnings $w_1 l_1 + w_2 l_2$.

2.3 Efficient Allocation

As a point of comparison to equilibrium allocations without and with income taxes, we first characterize the efficient allocation in this model economy. This allocation is the solution to the social planner's problem where the planer can directly choose consumption and labor supply to maximize household expected lifetime utility of the ex-ante identical households, subject only to an economy-wide resource constraint:

$$\max_{\{c_1, l_1, [c_2(s), l_2(s)]_{s \in S}\}} U(c_1, l_1) + \mathbf{E}\{U(c_2(s), l_2(s))\} \qquad \text{s.t.}$$

$$c_1 + \mathbf{E}\left\{c_2(s)\right\} = w_1 l_1 + \mathbf{E}\left\{w_2(s) l_2(s)\right\}. \tag{4}$$

The resource constraint (4) reflects the assumption that the planner also has access to the technology that can transfer resources between periods one for one. Note that the expectation $\mathbf{E}$ in the resource constraint is the expectation over productivity levels for each individual. With a law of large numbers this expectation is also the cross-sectional average across the continuum of households. The planner faces no risk and can freely allocate resources across individuals and thus (from the perspective of an individual), across idiosyncratic states of the world s. Proposition 1 provides a characterization of the efficient allocation.

Proposition 1 (Efficient Allocation)**.** *The efficient allocation* $\{c_1, l_1, [c_2(s), l_2(s)]_{s \in S}\}$ *is characterized by the following conditions:*

1. *Consumption Euler equation: for all* $s \in S$

$$U_c(c_1, l_1) = U_c(c_2(s), l_2(s)); \tag{5}$$

2. *Intratemporal optimality condition:*

$$-\frac{U_l(c_1, l_1)}{U_c(c_1, l_1)} = w_1, \quad \textit{and for all } s \in S, \quad -\frac{U_l(c_2(s), l_2(s))}{U_c(c_2(s), l_2(s))} = w_2(s), \tag{6}$$

and the resource constraint (4)*. The optimal allocation of labor is then characterized by:*

1. *Optimal allocation of labor between first and second period: for all* $s \in S$

$$\frac{U_l(c_1, l_1)}{w_1} = \frac{U_l(c_2(s), l_2(s))}{w_2(s)}; \tag{7}$$

2. Optimal allocation of labor across states in the second period: for all $s, s' \in S$

$$\frac{U_l(c_2(s'), l_2(s'))}{w_2(s')} = \frac{U_l(c_2(s), l_2(s))}{w_2(s)}. \tag{8}$$

Furthermore, suppose the period utility function is given by equation (1). Then the efficient allocation is given by

$$c_1 = c_2(s) = \left(\frac{\psi^{-\eta}}{2}\left[w_1^{1+\eta} + \mathbf{E}\left([w_2(s)]^{1+\eta}\right)\right]\right)^{\frac{1}{1+\sigma\eta}},$$

$$l_1 = \left(\frac{\psi^{-\frac{1}{\sigma}}[w_1]^{\frac{1}{\sigma}+\eta}}{\frac{1}{2}\left[[w_1]^{1+\eta} + \mathbf{E}\left([w_2(s)]^{1+\eta}\right)\right]}\right)^{\frac{\sigma\eta}{1+\sigma\eta}}, \quad \text{and} \quad l_2(s') = \left(\frac{\psi^{-\frac{1}{\sigma}}[w_2(s')]^{\frac{1}{\sigma}+\eta}}{\frac{1}{2}\left[[w_1]^{1+\eta} + \mathbf{E}\left([w_2(s)]^{1+\eta}\right)\right]}\right)^{\frac{\sigma\eta}{1+\sigma\eta}}.$$

Proof. See Appendix A.1. □

Proposition 1 states that the efficient allocation of labor equates the marginal disutility of producing one unit of output U_l/w (which we will refer to as the marginal disutility of earnings henceforth) across time and across states of the world. The social planner can separate this efficient allocation of labor from the efficient provision of consumption insurance, as governed by the risk-sharing equations (5). Furthermore, if the utility function takes the form in equation (1), then labor supply is increasing in labor productivity in the current period/state, and decreasing in expected labor productivity over the life cycle (the denominator). In the absence of income effects on labor supply $\sigma \to 0$, the efficient allocation of labor is determined exclusively by current labor productivity: $l_1 = (w_1/\psi)^\eta$ and $l_2(s) = (w_2(s)/\psi)^\eta$ for all s.

2.4 The Laissez-Faire Equilibrium

We first consider the competitive equilibrium without government interventions, i.e., the laissez-faire equilibrium. Recall that the government does not need to raise taxes to pay for government consumption, and thus net taxes sum to zero across all households. Proposition 2 provides the conditions governing the distribution of labor supply at such equilibrium, which are counterparts of (7) and (8) for the efficient allocation.[12]

Proposition 2 (Laissez-Faire Equilibrium)**.** *The laissez-faire equilibrium allocation $\{c_1, l_1, a, [c_2(s), l_2(s)]_{s\in S}\}$ is characterized by*

[12]Note that in this partial equilibrium setting, the laissez-faire equilibrium is equivalent to the constrained efficient allocation, where the notion of constrained efficiency with incomplete markets is based on Dávila et al. (2012), i.e, it is the allocation chosen by a planner who is constrained from completing financial markets spanning idiosyncratic wage risk. This planner problem imposes the additional constraint that consumption in the second period must be implementable with state non-contingent saving in the first period. In general equilibrium, the equivalence between competitive equilibrium- and constrained- efficient allocations no longer holds because the planner internalizes the impact of labor- and savings allocations on the marginal product of labor and capital whereas households in competitive equilibrium do not.

1. *Consumption Euler equation*

$$U_c(c_1, l_1) = \mathbf{E}\{U_c(c_2(s), l_2(s))\}; \tag{9}$$

2. *Intratemporal optimality condition*

$$-\frac{U_l(c_1, l_1)}{U_c(c_1, l_1)} = w_1, \quad \textit{and for all } s \in S, \quad -\frac{U_l(c_2(s), l_2(s))}{U_c(c_2(s), l_2(s))} = w_2(s), \tag{10}$$

and household budget constraints

$$c_1 + a = w_1 l_1, \quad \textit{and for all } s \in S, \ \ c_2(s) = w_2(s) l_2(s) + a. \tag{11}$$

These conditions imply the following equilibrium conditions for the allocation of labor:

1. *Allocation of labor between first and second period:*

$$\frac{U_l(c_1, l_1)}{w_1} = \mathbf{E}\left\{\frac{U_l(c_2(s), l_2(s))}{w_2(s)}\right\}; \tag{12}$$

2. *Allocation of labor across states in the second period: for all $s, s' \in S$,*

$$\frac{U_l(c_2(s'), l_2(s'))/w_2(s')}{U_l(c_2(s), l_2(s))/w_2(s)} = \frac{U_c(c_2(s'), l_2(s'))}{U_c(c_2(s), l_2(s))}. \tag{13}$$

Proof. See Appendix A.2. □

In comparison to the efficient allocation, Proposition 2 states that in the laissez-faire equilibrium, the marginal disutility of earnings U_l/w is equated only in expectation as stipulated in equation (12), rather than state-by-state as in (7). This reflects the missing insurance markets against the idiosyncratic risk, and hence households cannot adjust labor supply without changing their consumption in the same contingent way. Consequently, even if the marginal disutility of earnings is higher in one state, households might not shift labor supply away from this state because the associated consumption in that state would fall too much. This is evident from equation (13) which links the relative marginal disutility of earnings to the marginal utility of consumption in the laissez-faire equilibrium. In particular, the higher is the marginal utility of consumption (i.e., the lower is consumption) in a given state, the more households are willing to tolerate a higher marginal disutility of earnings (i.e., the more they work). The marginal disutility of earnings is still equalized over time in expectation because households can shift resources over time through state-non-contingent saving.

Because of missing insurance markets, by taxing households based on their earnings, a government may improve on the laissez-faire equilibrium by providing partial insurance against the idiosyncratic risk, but at the cost of further distorting the distribution of labor supply relative to the efficient benchmark in Proposition 1. That is, the government might want to tolerate additional distortions on labor supply in exchange for better insurance. This trade-off is the same in the presence of period taxation and lifetime income taxation, but how strong the two effects are, and what they imply for the optimal progressivity of the income tax code differ across the two tax systems.

2.5 Annual vs. Lifetime Income Taxes: Theory

We now characterize the equilibrium labor allocations, both under annual and lifetime income taxes in the two-period model, and compare them to the efficient allocation in Section 2.3 and the laissez-faire equilibrium in Section 2.4. Proposition 3 reports the conditions characterizing the distribution of labor supply at the Ramsey equilibrium under annual and lifetime income taxes, which are counterparts of those in Proposition 1 for the efficient allocation and Proposition 2 for the laissez-faire equilibrium.

Proposition 3 (Annual vs. Lifetime Income Taxes)**.** *For a given tax system, the equilibrium allocation is characterized by the distribution of labor supply:*

1. *Allocation of labor between first and second period:*
   (a) *Annual income tax:*
$$\frac{U_l(c_1, l_1)}{w_1[1 - T'(w_1 l_1)]} = \mathbf{E}\left\{\frac{U_l(c_2(s), l_2(s))}{w_2(s)[1 - T'(w_2(s) l_2(s))]}\right\}; \tag{14}$$
   (b) *Lifetime income tax:*
$$\frac{U_l(c_1, l_1)}{w_1} = \mathbf{E}\left\{\frac{U_l(c_2(s), l_2(s))}{w_2(s)}\right\}. \tag{15}$$
2. *Allocation of labor across states in the second period: $\forall s, s'$,*
   (a) *Annual income tax:*
$$\frac{U_l(c_2(s'), l_2(s'))/w_2(s')}{U_l(c_2(s), l_2(s))/w_2(s)} = \left[\frac{1 - T'(w_2(s') l_2(s'))}{1 - T'(w_2(s) l_2(s))}\right] \frac{U_c(c_2(s'), l_2(s'))}{U_c(c_2(s), l_2(s))}; \tag{16}$$
   (b) *Lifetime income tax:*
$$\frac{U_l(c_2(s'), l_2(s'))/w_2(s')}{U_l(c_2(s), l_2(s))/w_2(s)} = \left[\frac{1 - T'(w_1 l_1 + w_2(s') l_2(s'))}{1 - T'(w_1 l_1 + w_2(s) l_2(s))}\right] \frac{U_c(c_2(s'), l_2(s'))}{U_c(c_2(s), l_2(s))}. \tag{17}$$

Proof. See Appendix A.3. □

First, under both annual and lifetime income taxes, the marginal disutility of earnings is equated across time only in expectation, as opposed to this relation holding state-by-state in the efficient allocation stipulated by equation (7). This is again the consequence of incomplete insurance markets against idiosyncratic wage risk and the assumed absence of state-contingent lump-sum transfers/taxes. Furthermore, equation (14) shows that with an annual income tax, it is the marginal disutility of *after-tax* earnings that in expectation is equated over time, instead of the marginal disutility of (pre-tax) earnings in the laissez-faire equilibrium. Consequently, variations in the marginal tax rate across periods distort labor supply intertemporally. If the annual income tax is progressive and thus the marginal tax rate is increasing in labor income, then labor supply in high-productivity (and thus high income) periods is depressed relative to that in low-productivity periods. In contrast, equation (15) reveals that a lifetime income tax, even when progressive, introduces no distortion along this margin, and labor supply satisfies the same intertemporal optimality condition for labor supply as in the laissez-faire equilibrium, see equation (12).

Across states in the second period, both the annual and lifetime income taxes add additional distortions to household labor supply, relative to the laissez-faire equilibrium. Comparing equations (16) and (17) to (13), with distortionary taxes the marginal disutility of earnings across states is not only linked to the marginal utility of consumption (as in laissez-faire), but also to the state-contingent marginal tax rate. Both income taxes reduce relative labor supply when marginal tax rates are high. Note, however, that the difference in marginal tax rate across states tends to be smaller under a LIT because the marginal tax rate is determined by lifetime earnings rather than current earnings, and these lifetime earnings are less sensitive to the (state-contingent) earnings in the current period. As a result, the distribution of labor supply across contingent states follows that of labor productivity (as the efficient allocation stipulates) more strongly when the tax base is lifetime income than when it is annual income. Thus, the simple model suggests that a LIT tends to induce a more efficient distribution of labor supply than an annual income tax: it introduces no distortion intertemporally and less distortion across states. When income taxes are progressive, households will work longer hours when their labor productivity is high under a LIT than under an AIT. Aggregate labor efficiency, measured as total earnings divided by total hours, will then be higher under this tax system, and this is the key advantage of a LIT.

However, the property that a LIT does not distort labor supply across periods can be a disadvantage when market incompleteness prevents explicit consumption insurance; in contrast to the planner solution, the efficient allocation of labor cannot be separated from the efficient provision of consumption insurance. The lower is second-period labor supply, the less impactful are idiosyncratic uninsurable wage shocks for consumption risk. Therefore, for consumption insurance purposes it could be welfare improving to impose higher tax rates during high-earnings periods. This is, however, impossible under a LIT because as equation (15) shows, this tax system does not distort labor supply intertemporally. Therefore there exists a nontrivial trade-off between the labor efficiency benefits and the consumption insurance costs of lifetime income taxes relative to annual income taxes. In the remainder of this paper we quantify this trade-off, first in the simple model, in order to identify the main quantitative determinants of this trade-off, and then in a fully fledged life cycle model of intertemporal labor supply, precautionary saving, and social insurance.

2.6 Annual vs. Lifetime Income Taxes: Quantitative Exploration

The efficient allocation in Section 2.3 features: i) an efficient distribution of labor, with equal marginal disutility of earnings U_l/w over the life cycle and across idiosyncratic states; ii) an efficient distribution of consumption, with equal marginal utility of consumption U_c over the life cycle and across idiosyncratic states; and iii) efficient levels of consumption and labor such that the marginal disutility of earnings equals the marginal utility of consumption.

Due to incomplete markets and distortionary taxes, the market equilibrium in laissez-faire or under annual- or lifetime income taxes fails to attain the efficient allocation, resulting in lower welfare levels than with the efficient allocation. To quantify these deviations and the severity of distortions causing them, we introduce the following five wedges:

1. *Intertemporal labor wedge*: a "tax" on relocating labor (earnings) from first to second period. For each unit reduction in first-period earnings, the required expected earnings increase in the second period to compensate the first-period earnings loss is $1+\chi_{\text{lab}}^{\text{LC}}$:
$$\frac{U_{l_1}}{w_1} = (1+\chi_{\text{lab}}^{\text{LC}})\mathbf{E}\left\{\frac{U_{l_2}}{w_2}\right\}.$$
2. *Labor dispersion wedge*: a "tax" on relocating labor (earnings) from the low- to high-wage state in the second period. For each unit of earnings reduction in the low-wage state, the required earnings increase in the high-wage state is $1+\chi_{\text{lab}}^{\text{AS}}$:
$$\frac{U_{l_2^L}}{w_2^L} = (1+\chi_{\text{lab}}^{\text{AS}})\left(\frac{U_{l_2^H}}{w_2^H}\right).$$
3. *Intertemporal consumption wedge*: a "tax" on relocating consumption from the first to the second period, i.e., a savings tax. For each unit of reduction in the first-period consumption, the second-period consumption only increases by $1-\chi_{\text{cons}}^{\text{LC}}$:
$$U_{c_1} = (1-\chi_{\text{cons.}}^{\text{LC}})\mathbf{E}\{U_{c_2}\}.$$
4. *Consumption dispersion wedge*: a "tax" on relocating consumption from the high- to low-wage state in the second period. For each unit of consumption reduction in the high-wage state, the low-wage state consumption only increases by $1-\chi_{\text{cons.}}^{\text{AS}}$:
$$U_{c_2^H} = (1-\chi_{\text{cons}}^{\text{AS}})U_{c_2^L}.$$
5. *Consumption-labor wedge*: a labor income "tax" in the first period on converting labor to consumption. For each unit of earnings, consumption only rises by $1-\chi_{\text{cons,lab}}$:
$$-\frac{U_{l_1}}{w_1} = (1-\chi_{\text{cons.,lab}})U_{c_1}.$$

The intertemporal and labor (consumption) dispersion wedges capture inefficiencies in the allocation of labor (consumption) over time and across idiosyncratic states, respectively.

The consumption-labor wedge measures distortions in the levels of consumption and labor. If all five wedges are zero and the resource constraint (4) is satisfied, the allocation is efficient.

Table 1 summarizes the formal definitions of wedges and presents their signs under various equilibria in the columns denoted "Wedge Signs". In the laissez-faire equilibrium, there are no distortions over time or between consumption and labor, and hence the intertemporal and consumption-labor wedges are zero. However, due to missing insurance markets, the distributions of labor and consumption are inefficient across idiosyncratic states. Specifically, the labor and consumption dispersion wedges are both positive, implying too little labor and too much consumption in the high-wage state relative to the low-wage state.

Table 1: Wedges in the Two-Period Model

		I. Wedge Signs				II. When Progressivity $\uparrow$		
Wedges	Definition	Efficient	LF	AIT	LIT	AIT	LIT	Compare
A. Labor Distribution								
Intertemporal	$\frac{U_{l_1}/w_1}{\mathbf{E}\{U_{l_2}/w_2\}} - 1$	0	0	$\gtreqless 0$	0	$\uparrow$	$\rightarrow$	LIT>AIT
Dispersion	$\frac{U_{l_2^L}/w_2^L}{U_{l_2^H}/w_2^H} - 1$	0	>0	>0	>0	$\downarrow$	$\downarrow\downarrow$	LIT>AIT
B. Consumption Distribution								
Intertemporal	$1 - \frac{U_{c_1}}{\mathbf{E}\{U_{c_2}\}}$	0	0	0	0	$\rightarrow$	$\rightarrow$	LIT=AIT
Dispersion	$1 - \frac{U_{c_2^H}}{U_{c_2^L}}$	0	>0	>0	>0	$\downarrow\downarrow$	$\downarrow$	LIT<AIT
C. Levels of Consumption and Labor								
Consumption-Labor	$1 + \frac{U_{l_1}/w_1}{U_{c_1}}$	0	0	$\gtreqless 0$	$\gtreqless 0$	$\uparrow$	$\uparrow\uparrow$	LIT<AIT

Notes: "LF" denotes the laissez-faire equilibrium. For Column Group II, results are based on the parameterized two-period model with $\mathbf{E}\{w_2\}/w_1 = 1.109$ and $\Delta = 0.303$. The symbols $\uparrow$, $\downarrow$, and $\rightarrow$ indicate an increase, decrease, or no change, respectively, while double arrows represent stronger effects.

A progressive AIT distorts labor supply decisions over time as the tax rate is higher in periods with more earnings, and thus the intertemporal labor wedge may be positive or negative. Proposition 3 states that a LIT introduces no such distortion, and therefore, the intertemporal labor wedge is zero. Both progressive annual and lifetime income taxes may provide partial insurance against wage risks. However, because insurance remains incomplete and labor supply is distorted, the labor and consumption dispersion wedges are positive. The consumption-labor wedge may be positive or negative, depending on the overall tax level.

2.6.1 Parameterization

To illustrate the heterogeneous effects of lifetime and annual income taxes on the wedges and identify their key determinants and consequences for welfare, we parameterize the two-period model and solve it numerically under various fiscal constitutions. The period utility function is additively separable between consumption and labor and given by (1). We choose

$\sigma = 1.5$ and $\eta = 0.5$ as in our quantitative analysis, and the parameter ψ is normalized to 1 for simplicity. The first-period wage w_1 is deterministic, but there is idiosyncratic wage risk in the second period. The expected wage is denoted by $\mathbf{E}\{w_2\} = 1$, but it can take the values $w_2^H = 1 + \Delta$ or $w_2^L = 1 - \Delta$ with equal probability. Therefore, $\mathbf{E}\{w_2\}/w_1 = 1/w_1$ is the expected wage growth from the first to the second period, and Δ measures the extent of idiosyncratic wage risk (its standard deviation) in the second period.

Following Bénabou (2002) and Heathcote et al. (2017), and consistent with our quantitative analysis, we adopt a two-parameter functional form for both the AIT and LIT:

$$T_X(y) = y - (1 - \tau_X)y^{1-\mu_X}, \; X \in \{A, L\},$$

where y denotes pre-tax earnings, and μ_X and τ_X are policy parameters governing the progressivity and the level of income tax. The subscript A and L represent annual and lifetime income taxes. For the status quo AIT, the tax progressivity and level are set to 0.137 and 0.105, as in our quantitative analysis. Note that Proposition 4 and Corollary 1 in Appendix A.4 demonstrate that with the aforementioned assumptions in the two-period model, all wedges—except for the consumption-labor wedge—remain invariant with respect to the tax *level* parameter τ, under both the AIT and LIT systems.

2.6.2 LIT vs. AIT: Fixed Progressivity

We now examine the effects of replacing the status quo AIT with a LIT of the same progressivity, highlighting the key role of the wage process in shaping the results. The tax level parameter for the LIT is determined endogenously to match the tax revenue of the status quo policy. The top four panels of Figure 1 compare distortions introduced by both tax systems, measured by the absolute values of wedges defined in Table 1. The horizontal axis $\mathbf{E}\{w_2\}/w_1$ represents expected wage growth across the two periods, while the vertical axes Δ indicate the level of wage risk in the second period. A positive value (blue color) indicates a smaller wedge under LIT than under AIT, implying less distortions by LIT.

The intertemporal labor wedge is zero under LIT (as in the efficient allocation), whereas under AIT, the wedge may be positive or negative, indicating distortions (top-left panel). LIT also leads to a smaller labor dispersion wedge (i.e., a more efficient labor distribution within the second period) compared to AIT, except when wage growth is high and wage risk is small. Even when AIT outperforms LIT (red area), the advantage is small. In contrast, when LIT performs better (blue area), the difference is more substantial.

The middle-left panel illustrates the consumption dispersion wedge, which measures the degree of consumption insurance between the low- and high-wage states. AIT provides better consumption insurance when wage growth is significant and wage risk is moderate. The intuition is that when average earnings increase between the two periods, AIT effectively

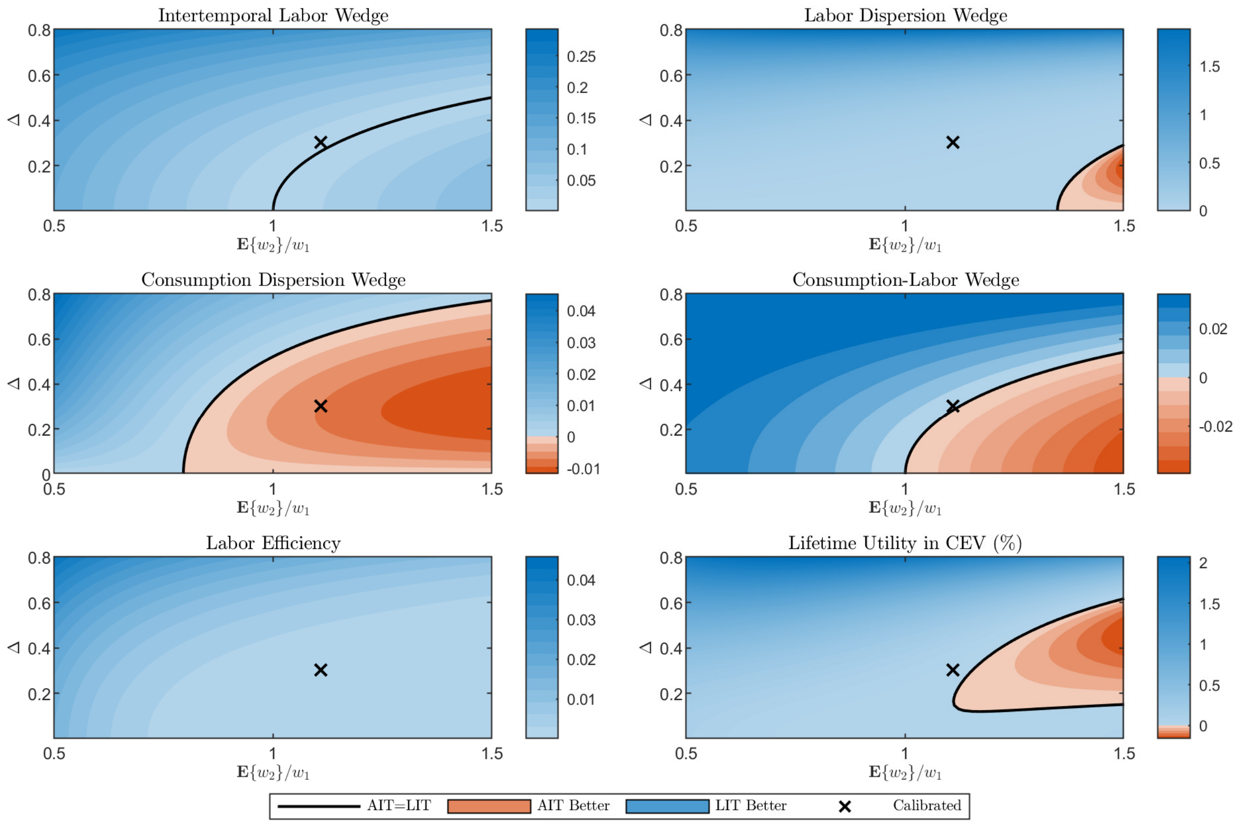

Figure 1: LIT vs. AIT: Fixed Progressivity

Notes: This figure compares LIT and AIT under the same tax progressivity. The horizontal axis measures average wage growth between two periods, while the vertical axis measures wage risk in the second period. The top four panels display differences in the absolute values of wedges; the bottom-left and bottom-right panels show differences in labor efficiency and lifetime utility. A positive value (blue areas) indicates that LIT has smaller wedges than AIT, higher labor efficiency, or greater lifetime utility—by that magnitude. A negative value (red areas) implies the opposite. Tax progressivity is set at $\mu_A = \mu_L = 0.137$. The tax level parameter is $\tau_A = 0.105$ and for the LIT, τ_L is endogenously determined to generate the same tax revenue as AIT. The "**x**" symbol in the plots represent the calibrated wage growth and wage risk, based on the differences in trend wage and the variance of log wages between age 35 and 55 in the PSID, and thus signifies the parameterization of $\mathbf{E}\{w_2\}/w_1$ and Δ we view as most informative.

mimics an age-dependent tax with a higher tax rate in the second period, thereby reducing second-period labor supply. Since wage risk is concentrated in the second period, this mechanism helps mitigate its impact on household consumption. The middle-right panel depicts the consumption-labor wedge, which measures the efficiency trade-off between the overall level of consumption and labor supply. AIT dampens labor supply less (i.e., introduces a smaller wedge) when wage growth is substantial and wage risk is small.

As indicated by the top two panels, LIT generally introduces less distortions to labor supply decisions. Consequently, aggregate labor efficiency, defined as the ratio of total earnings to total hours worked, is consistently higher under LIT than AIT, as shown in the bottom-left panel of Figure 1. In contrast, AIT tends to offer better consumption insurance and may have a smaller depressive effect on overall labor supply.

Given the respective advantages and disadvantages of LIT and AIT, which one induces a higher level of social welfare is a quantitative question. The bottom-right panel of Figure 1 illustrates the difference in lifetime utility under LIT and AIT in terms of consumption-equivalent variation. LIT outperforms AIT when wage growth is modest or negative, regardless of wage risk, as well as when wage growth is significant and wage risk is either small or large (blue area). However, AIT can surpass LIT in cases where wage growth is significant and wage risk is moderate (red area).

The "**x**" symbol in Figure 1 marks the wage process with $\mathbf{E}\{w_2\}/w_1 = 1.109$ and $\Delta = 0.303$, calibrated to match the differences in trend wage and log-wage variance between ages 35 and 55 in the PSID. With this calibration, the labor efficiency gain from LIT outweighs the consumption insurance loss, resulting in higher lifetime utility under LIT than AIT. However, this experiment corresponds to a shift from a semi-lifetime income tax to a LIT. In reality, the status quo policy operates at an annual frequency, various types of idiosyncratic wage shocks are resolved gradually over the life cycle, and the life-cycle wage profile is hump-shaped, not monotonic. Thus, assessing the consequences of a LIT requires a full life-cycle model that captures these features, motivating quantitative analysis below.

2.6.3 LIT vs. AIT: Varying Progressivity

Column group II of Table 1 summarizes the theoretical effects of increasing tax progressivity on the wedges, both under LIT and AIT. Figure 2 illustrates how the wedges (in absolute value) vary with tax progressivity quantitatively. For this experiment, the wage process is the same as that marked by "**x**" in Figure 1, and the tax level parameters are determined endogenously to match the tax revenue of the status quo policy.

Increasing tax progressivity enhances labor efficiency under LIT, as the intertemporal wedge remains zero (solid blue line, top-left panel) and the labor dispersion wedge moves closer to zero (solid blue line, top-right panel). This reduction in the labor dispersion wedge occurs because a more progressive income tax improves consumption equality, thereby narrowing the gap in marginal utility of consumption between high- and low-wage states. As a result, labor supply increases in the high-wage state and decreases in the low-wage state when financial markets are incomplete. For AIT, greater progressivity also reduces the labor dispersion wedge (dashed red line, top-right panel) in this example, but less effectively than LIT.[13] Moreover, a more progressive AIT can introduce greater intertemporal labor

[13]It is worth noting that this reduction under AIT is not guaranteed. For instance, if Δ is doubled while other factors remain constant, the labor dispersion wedge increases with AIT progressivity. In contrast, under LIT, this wedge continues to decline with greater progressivity.

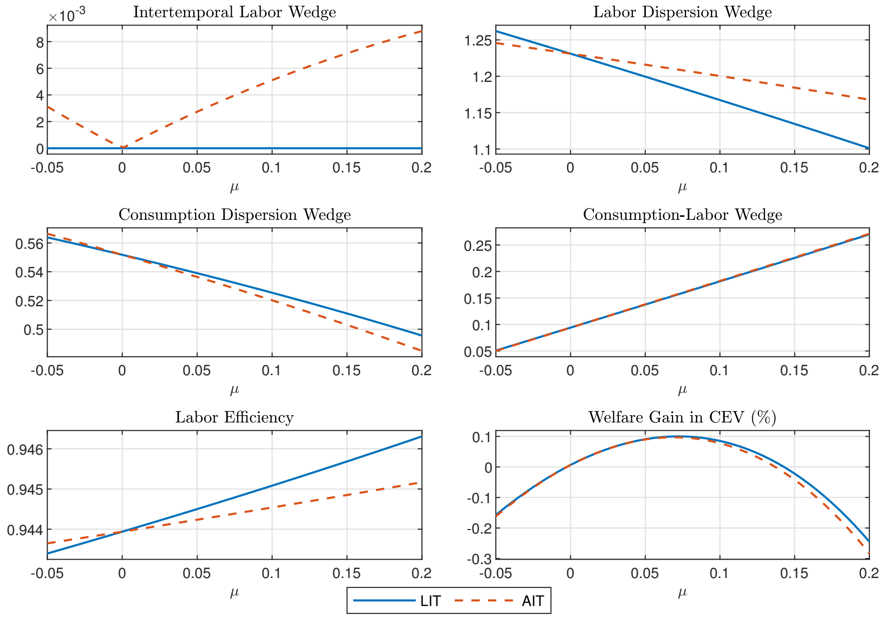

Figure 2: LIT vs. AIT: Varying Progressivity

Notes: This figure shows how wedges, labor efficiency, and lifetime utility change with tax progressivity μ under AIT and LIT. The top four panels display the absolute values of wedges, the bottom-left panel shows labor efficiency, and the bottom-right panel presents the change in lifetime utility relative to the status quo AIT. The tax level parameters τ_A and τ_L vary with μ to match the tax revenue under the status quo policy.

distortions (dashed red line, top-left panel, when $\mu > 0$), thereby reducing labor efficiency.

The middle-left panel shows that the primary benefit of a more progressive income tax is the reduction in the consumption dispersion wedge, i.e., better consumption insurance, leading to a more efficient distribution of consumption. The main drawback is a larger consumption-labor wedge, which further depresses labor supply relative to consumption, as shown in the middle-right panel. AIT appears to manage this trade-off more effectively by delivering a greater improvement in consumption insurance with a relatively smaller increase in the consumption-labor wedge. However, a more progressive LIT has the additional advantage of enhancing labor efficiency more, as demonstrated in the bottom-left panel.

3 The Quantitative Model

We now introduce the quantitative life-cycle model with heterogeneous households through which we interpret the data and evaluate the welfare and economic consequences of tax reform. We describe the maximization problems of households and firms, the role of government and two types of income tax policies, and then define a competitive equilibrium.

3.1 Households

Consider a stationary economy populated by overlapping generations of ex-ante and ex-post heterogeneous households. In each period, a continuum of measure one households is born at age 1. Households work in the first J_R years of their life cycles, then retire and live until their death after age J. We now describe the optimization problems of households at different stages of their life cycle in recursive formulation, indexing the current household state by $\mathbf{S}$ and next period's state by $\mathbf{S}'$.

3.1.1 Working Households

Between age 1 and age J_R, households can work and earn labor income y determined by their labor supply l and wage rate $\widetilde{w}$. The household's wage $\widetilde{w}$ is given by

$$\widetilde{w}(j, \alpha, z, \varepsilon; w) = w \exp\{\widetilde{e}(j) + \alpha + z + \varepsilon\},$$

where w is the price per effective unit of labor, $\widetilde{e}(j)$ is a deterministic life-cycle trend of labor productivity that is common among households, and (α, z, ε) are the idiosyncratic components of labor productivity. Specifically, $\alpha \sim N(0, \sigma_\alpha^2)$ is a household-specific fixed effect that is determined at birth and constant over the life cycle, and z is a persistent stochastic component that follows an AR(1) process, that is,

$$z' = \rho z + \nu, \;\; \nu \sim N(0, \sigma_\nu^2),$$

where ν is an idiosyncratic iid shock. Lastly, $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ is a transitory component of labor productivity that is iid across households and over time.

Financial markets are incomplete; households can borrow and save in a risk-free asset at interest rate r, subject to age-dependent and potentially binding borrowing constraints $\underline{a}_{j+1}$. However, insurance contracts that pay out contingent on the realization of idiosyncratic labor productivity shocks are ruled out by assumption, as is standard in the incomplete markets literature in macroeconomics, see, e.g., Bewley (1986), Huggett (1993) and Aiyagari (1994).

Four types of taxes are imposed by the government on working households: a labor income tax, a payroll tax, a capital income tax, and a consumption tax. The labor income tax policy is summarized by a function $\widetilde{T}(y, Y, j)$, which gives the current tax liability based on household current earnings y and, in the case of a lifetime income tax, the accumulated lifetime earnings *before the current period* Y and the household age j. Payroll taxes, capital income taxes, and consumption taxes are modeled as flat taxes on current earnings, capital income, and consumption with tax rates τ_{ss}, τ_k, and τ_c, respectively.

In each year, working households choose their consumption c, labor supply l, and future savings a' based on their current state $\mathbf{S} = \{a, Y, z, \varepsilon, j, \alpha\}$, where a is the household's current assets. A working household's decision problem in the recursive formulation is then:

$$V(\mathbf{S}) = \max_{\{c,l,a',Y'\}} \left\{ U(c, l) + \beta \mathbf{E}_{(z',\varepsilon')} \left[V(\mathbf{S}') | z \right] \right\} \quad \text{s.t.}$$

$$(1 + \tau_c)c + a' = y - \widetilde{T}(y, Y, j) - \tau_{ss} y + [1 + (1 - \tau_k)r]a;$$

$$y = [w \exp\{\widetilde{e}(j) + \alpha + z + \varepsilon\}]\, l;\;\; Y' = Y + \frac{y}{(1+r_d)^{j-1}};$$
$$z' = \rho z + \nu,\;\; \nu \sim N(0, \sigma_\nu^2);\;\; \varepsilon' \sim N(0, \sigma_\varepsilon^2);\;\; a' \geq \underline{a}_{j+1},\;\; c \geq 0,\;\; l \geq 0.$$

Here $U(c, l)$ is the period utility function, β is the time discount factor, and r_d is the discount rate chosen by the government for computing lifetime earnings.

3.1.2 Retired Households

Households retire at age J_R and receive retirement benefits b from the government in each year that depend on their average earnings $\bar{y}$ across working years. Benefits are determined by the benefit function $b = \widetilde{b}(\bar{y})$ where average earnings $\bar{y}$ are implicitly defined by:

$$Y_{J_R+1} = \sum_{j=1}^{J_R} \frac{y_j}{(1+r_d)^{j-1}} = \sum_{j=1}^{J_R} \frac{\bar{y}}{(1+r_d)^{j-1}}. \tag{18}$$

Retired households consume and save in the risk-free bond, pay consumption and capital income taxes, and they die after age J. Since retirement benefit is fixed once determined, the state variables of retired households are only $\mathbf{S} = \{a, b, j\}$ and their decision problems are

$$\begin{aligned} V^R(\mathbf{S}) &= \max_{\{c, a'\}} \left\{ U(c, 0) + \beta V^R(\mathbf{S}') \right\} \quad \text{s.t.} \\ (1+\tau_c)c + a' &= b + [1 + (1-\tau_k)r]a;\;\; a' \geq \underline{a}_{j+1},\;\; c \geq 0. \end{aligned}$$

3.2 Firms

The production side of the economy consists of representative, profit-maximizing firms. They rent capital K at interest rate r and hire effective labor N at price w to produce the final good used for both consumption and investment. All the firms have the same constant returns to scale production technology $F(K, N)$, and markets are perfectly competitive. Thus, all firms make zero profits in equilibrium; without loss of generality we can focus on a representative firm who takes input and output prices as given and maximizes period profit:

$$\max_{(K,N)} F(K, N) - \delta K - wN - rK$$

where δ is the capital depreciation rate.

3.3 The Government

The government collects labor income taxes, payroll taxes, capital income taxes, and consumption taxes from households to finance three types of expenditures: (1) retirement benefits, (2) expenditures on public goods, and (3) interest payments on government debt.

3.3.1 Annual vs. Lifetime Income Tax

We consider two types of labor income tax systems. The first is an annual income tax (AIT) as currently adopted by most countries. Under such policy, annual tax liabilities of each household depend only on current-year earnings y, and the tax function reduces to

$$\widetilde{T}(y, Y, j) = T(y),$$

where $T(\cdot)$ specifies the mapping from a household's current earnings y to its current tax liability $T(y)$. The second type of income tax system we consider is a lifetime earnings tax (LIT) in which the total tax liability of a household depends on accumulated earnings over the life cycle. There are different ways of implementing such a LIT; a simple one is to set the tax function

$$\widetilde{T}(y, Y, j) = \left[T\left(Y + \frac{y}{(1+r_d)^{j-1}}\right) - T(Y)\right](1+r_d)^{j-1},$$

where $T(\cdot)$ now specifies the mapping from a household's lifetime earnings to their total tax liability, both in present discounted values with discount rate r_d. That is, at age j, households only pay the increase in their total tax liability due to the addition of their current-year earnings in present value $\frac{y}{(1+r_d)^{j-1}}$ to their accumulated lifetime earnings before the current period Y. The $(1+r_d)^{j-1}$ term converts the tax due back to age-j values as it is paid at age j. It is easy to verify that the present discounted value of all tax payments over a household's working life is given by

$$\sum_{j=1}^{J_R} \frac{\widetilde{T}(y_j, Y, j)}{(1+r_d)^{j-1}} = T\left(\sum_{j=1}^{J_R} \frac{y_j}{(1+r_d)^{j-1}}\right),$$

and thus is a function only of the present discounted value of realized labor earnings over the household's working life.[14]

3.3.2 Government Budget

The stationary government period budget constraint is

$$\sum_{j=1}^{J} \int \left[\widetilde{T}(y, Y, j) + \tau_{ss} y + \tau_c c + \tau_k r a - b\right] d\Phi_j(\mathbf{S}) = G + rB, \tag{19}$$

where $\mathbf{S}$ is the collection of household states, and $\Phi_j(\mathbf{S})$ is the measure of age-j households with state $\mathbf{S}$ in the population. G denotes government expenditures on public goods, and B is the amount of government debt. Note that household earnings y, lifetime earnings Y, consumption c, savings a, and retirement benefit b all depend on the household state $\mathbf{S}$. The left-hand side of the budget constraint is the government's net revenues from households, i.e., taxes minus retirement benefits, and the right-hand side gives the government expenditures on public goods and interest payments on government debt.

[14] This implementation of the lifetime income tax has (at least) two desirable properties: first, as long as the marginal tax rate is below 100%, households can always afford paying taxes with their current earnings; and second, the government still collects taxes at annual frequency, and no household accumulate tax liabilities over time.

3.4 Definition of Stationary Competitive Equilibrium

Given government tax policy $\{\widetilde{T}(\cdot), \tau_{ss}, \tau_k, \tau_c\}$, retirement benefit function $\widetilde{b}(\cdot)$, government debt B, and the measure of state for newborn households $\Phi_1(\cdot)$, a stationary competitive equilibrium is a collection of household value and policy functions $\{V, c, l, a'\}$, the representative firm's decisions $\{K, N\}$, expenditures on public goods G, the price of effective labor w, interest rate r, and a sequence of measures for household state $\{\Phi_j(\cdot)\}_{j=2}^{J}$ such that

1. Given prices $\{w, r\}$, tax policy $\{\widetilde{T}(\cdot), \tau_{ss}, \tau_k, \tau_c\}$ and retirement benefit function $\widetilde{b}(\cdot)$, the value and policy functions $\{V, c, l, a'\}$ solve the household optimization problem.
2. Representative firm: Given the prices $\{w, r\}$, the values of $\{K, L\}$ solve the representative firm's profit maximization problem.
3. Given the tax policy $\{\widetilde{T}(\cdot), \tau_{ss}, \tau_k, \tau_c\}$, given the retirement benefit function $\widetilde{b}(\cdot)$, given government debt B, and given household policy functions $\{c, l, a'\}$ and population $\{\Phi_j(\cdot)\}_{j=1}^{J}$, the value of G satisfies the government period budget constraint (19).[15]
4. The labor market, capital market, and goods markets clear:

$$N = \sum_{j=1}^{J} \int \frac{\widetilde{w}(j, \alpha, z, \varepsilon)}{w} l(\mathbf{S}) d\Phi_j(\mathbf{S}); \qquad K = \sum_{j=1}^{J} \int a d\Phi_j(\mathbf{S}) - B;$$

$$\sum_{j=1}^{J} \int c(\mathbf{S}) d\Phi_j(\mathbf{S}) + G = F(K, N) - \delta K.$$

5. Given $\Phi_1(\cdot)$, the laws of motion for $\{\Phi_j(\cdot)\}_{j=1}^{J}$ induced by the household policy functions, demographics, and idiosyncratic shocks, $\{Q_j(\cdot)\}_{j=1}^{J-1}$, satisfy $\Phi_{j+1} = Q_j(\Phi_j)$ for all j.

4 Calibration

In this section, we describe how we parameterize the model to map it into U.S. data. We first introduce the main data sources, and then explain our calibration strategy and report the calibrated values of parameters. Lastly, we evaluate the model's performance in replicating the empirical life cycles of household variables and their dispersions.

4.1 Data

Our main data source is the core sample of the 1999-2017 Panel Study of Income Dynamics (PSID), from which we obtain individual and household level information about earnings, hours worked, consumption, net worth, and characteristics such as age, race, education, number of children etc. Since our model does not differentiate between single and married households, all household level data are normalized by the number of adults in the

[15] Note that the stationary government period budget constraint (19) is used solely to calibrate the value of government expenditures G. In our optimal policy exercises, we always impose a *within-cohort* government budget constraint guaranteeing that all tax policies collect the same tax revenues from a newborn cohort.

household (head and spouse only) before comparing to their model counterparts. Wages are constructed as earnings divided by hours worked.[16]

4.2 Calibration Strategy

The model is calibrated to match the U.S. economy based on simulated economies at the stationary competitive equilibrium with 100,000 households in each cohort.

4.2.1 Demographics

Each model period represents one year in the data. Age 1 corresponds to data age 25, and the length of life cycle J is set to 55 based on the U.S. life expectancy of 79. The retirement age J_R is set to 42 in the model, i.e., data age 66 according to the U.S. social security rules.

4.2.2 Preferences

Household preferences are additively separable between consumption and labor, and the period utility function takes the functional form in equation (1). The parameter σ governs household risk aversion, the parameter η is the Frisch elasticity of labor supply with respect to wage, and ψ controls the level of disutility from labor. To match the earnings and hours inequality in the data, as in Kaplan (2012) and Heathcote et al. (2017), we allow for preference heterogeneity in the disutility of working and assume $\ln \psi \sim N\left(\ln \bar{\psi}, \sigma_{\psi}^2\right)$ in the population, in which $\bar{\psi}$ controls the level of disutility, and σ_{ψ}^2 its dispersion. The value of $\bar{\psi}$ is calibrated to match the average earnings of age 25-60 households, which is normalized to one in the model economy. σ_{ψ}^2 is pinned down by the covariance between log earnings and log hours worked in the PSID sample, which is 0.096.[17]

The value of σ in the literature typically ranges between 1 (i.e., log utility) and 2, and thus we choose the middle value of 1.5. We set the labor supply elasticity η to 0.5, broadly consistent with the microeconomic evidence on the Frisch elasticity. The discount factor β is calibrated to match the average net worth of age 51-60 households, which is 5.405 in model units, or $293,194 per adult in 2016 dollars, according to the PSID sample.

4.2.3 Wage Process

For the deterministic life-cycle trend of labor productivity $\widetilde{e}(j)$, we regress the log-wage from the PSID on a 4th-degree polynomial in age, together with a group of household controls for the year, education, gender, marital status, race, and location, etc. The age profile of log-wage are then constructed as the predicted values from this regression at different ages while integrating over the remaining covariates. The resulting wage trend is presented in

[16] All nominal variables are converted to values in 2016 U.S. dollars based on the consumer price index for all urban consumers (CPI-U) from the U.S. Bureau of Labor Statistics. One unit of income in the model corresponds to the average earnings of households aged 25-60 in the PSID sample, which is $54,248 per adult.

[17] The advantage of targeting this covariance is that it is immune to the existence of classical measurement errors in earnings and hours worked.

Figure 9 of Appendix B.

For the persistent AR(1) component z and the transitory component ε of labor productivity, the parameters are set to the values estimated by Kaplan (2012). In particular, the persistence of the AR(1) component ρ is 0.958, the variance of the persistent shock σ_ν^2 is 0.017, and the variance of the transitory shock σ_ε^2 is 0.081. The initial draw of the persistent component is set to zero.

The variance of the fixed effect of labor productivity σ_α^2 is calibrated to match the variance of the log-wage of young (age-25) households in the PSID sample. Specifically, it is computed as the aforementioned variance of log-wage minus the variances of the transitory component and measurement errors. Following the literature, the variance of measurement error in wage is set to 0.02.[18] The resulting variance of the fixed effect is 0.149.

4.2.4 Government Policies

Income, capital, and consumption taxes. For the status quo economy with annual income tax, following Bénabou (2002) and Heathcote et al. (2017), we approximate the U.S. tax-and-transfer system with a two-parameter tax function of the form:

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

where μ and τ are two parameters governing the progressivity and level of income tax. The values of these parameters are set based on the estimates by Wu (2021), which combine the federal and state income taxes and include government transfers as negative taxes. The tax progressivity parameter μ is 0.137, and the tax level parameter τ is set to 0.105 such that the average income tax rate of the median income household is 7.8%.

The capital income tax rate τ_k and consumption tax rate τ_c are also from Wu (2021), estimated using the OECD aggregate data, following closely the method in Mendoza et al. (1994) and Trabandt and Uhlig (2011). The capital income tax rate τ_k is 33.0%, and the consumption tax rate τ_c is 4.1%.

Payroll tax and retirement benefit. The payroll tax rate τ_{ss} is set to 12.4% based on the actual Social Security tax rates. Like the U.S. social security system, the retirement benefit in the model is a piecewise-linear function of the household's average earnings before retirement $\bar{y}$, defined in equation (18). In particular, the retirement benefit of a household

[18] Since wage is computed as earnings divided by hours worked, the variance of measurement error in wage follows from our assumption of zero measurement error in earnings and classical measurement error of variance 0.02 in log hours. The assumption of zero measurement error in earnings is consistent with the empirical findings in Kaplan (2012) and Heathcote et al. (2014).

with average earnings $\bar{y}$ is given by

$$\widetilde{b}(\bar{y}) = \begin{cases} \xi_{b,1}\bar{y} & \text{if } \bar{y} \leq b_1; \\ \xi_{b,1}b_1 + \xi_{b,2}(\bar{y} - b_1) & \text{if } b_1 < \bar{y} \leq b_2; \\ \xi_{b,1}b_1 + \xi_{b,2}(b_2 - b_1) + \xi_{b,3}(\bar{y} - b_2) & \text{if } b_2 < \bar{y} \leq b_3; \\ \xi_{b,1}b_1 + \xi_{b,2}(b_2 - b_1) + \xi_{b,3}(b_3 - b_2) & \text{if } \bar{y} > b_3. \end{cases}$$

Following the actual U.S. policy, we set $\xi_{b,1}$, $\xi_{b,2}$, and $\xi_{b,3}$ to 0.9, 0.32, and 0.15, respectively; and b_1, b_2, and b_3 equal 0.21, 1.29, and 2.42 times the average earnings in the economy. In other words, the marginal replacement rate is 90% up to 0.21 times the average earnings in the economy, 32% between 0.21 and 1.29 times the average earnings, 15% between 1.29 and 2.42 times the average earnings, and 0% above.

Government debt and expenditure. The amount of government debt B is set to target a debt-to-output ratio of 60%, resulting in $B = 39.63$. The stationary government period budget constraint, equation (19), then implies that government expenditures on public goods, as a fraction of GDP is $G/Y = 12.5\%$.

4.2.5 Initial Asset and Borrowing Limits

The distribution of household initial asset when entering the economy is calibrated from the PSID. In particular, we approximate the empirical distribution of net worth of young (age-25) households by a discrete distribution with twenty mass points of equal probability (i.e., 5% each). The initial assets of newborn households in the model are then drawn randomly from this discrete distribution.[19]

To be consistent with the distribution of initial asset, the borrowing limit at the beginning of household life cycle is set to the lowest mass point of the discretized distribution of initial asset, which is -1.080 in model units, or $-\$58,605$ per adult in 2016 dollars. The borrowing limit is tightened gradually as households age such that it reaches zero at retirement.[20]

4.2.6 Production Technology and Factor Prices

We consider two functional forms for the constant-return-to-scale production function $F(K, N)$. As baseline, we assume a linear production technology:

$$F(K, N) = [(r + \delta)K + wN]. \tag{20}$$

This formulation implies that the interest rate and the wage per efficiency unit of labor (r, w) are invariant to changes in tax policy. Thus, our baseline analysis considers a partial

[19]The correlation between net worth and log-wage of young households is close to zero in the data, therefore initial asset is assumed to be independent of initial labor productivity in the model.

[20]Figure 10 of Appendix B presents the share of borrowing constrained households in the calibrated model.

Table 2: Model Parameters

Parameter	Governing	Value
A. Demographics		
(J_R, J)	retirement age and life expectancy	$(42, 55)$
B. Preferences		
(σ, η, β)	risk aversion, labor elasticity, and discount factor	$(1.5, 0.5, 0.992)$
$(\bar{\psi}, \sigma_\psi^2)$	level and dispersion of labor disutility	$(2.045, 0.788)$
C. Wage Process		
(ρ, σ_ν^2)	persistence and variance of persistent shocks	$(0.958, 0.017)$
σ_ε^2	variance of transitory shocks	0.081
σ_α^2	variance of fixed effect	0.149
D. Taxes		
(μ, τ)	income tax progressivity and level	$(0.137, 0.105)$
$(\tau_c, \tau_k, \tau_{ss})$	consumption, capital, and payroll taxes	$(0.041, 0.330, 0.124)$
E. Retirement Benefit		
(b_1, b_2, b_3)	cutoff levels of average earnings	$(0.21, 1.29, 2.42)$
$(\xi_{b,1}, \xi_{b,2}, \xi_{b,3})$	marginal replacement rates	$(0.90, 0.32, 0.15)$
F. Factor Prices and Technology		
(r, w)	interest rate and price of effective labor	$(3\%, 1)$
(Z, ζ, δ)	TFP, capital share, and depreciation rate	$(1.000, 0.330, 0.116)$
G. Others		
(B, G)	government debt and expenditure	$(39.63, 8.24)$

equilibrium framework with fixed factor prices.[21] The interest rate r is set at 3%, and the price of effective labor w is normalized to one. Alternatively, we conduct a general equilibrium analysis in Section 6.2 where the production function takes a Cobb-Douglas form:

$$F(K, N) = ZK^{\zeta}N^{1-\zeta}. \tag{21}$$

We set the capital share ζ to 0.33. Total factor productivity Z is calibrated so that the equilibrium price of effective labor w is exactly one (normalization). The capital depreciation rate δ is chosen to ensure an equilibrium interest rate of $r = 3\%$. Table 2 summarizes the calibration of the model and the values of model parameters.

4.3 Goodness of Model Fit

We now examine the model's performance in explaining the data by comparing household life-cycle profiles generated by the model with those estimated from the PSID data.[22] These profiles are not directly targeted in calibration. The model closely replicates the life-cycle profiles of key household variables and their dispersions. Consequently, it is a suitable

[21] Alternatively, we can interpret the benchmark as an open-economy setting with a fixed global interest rate and free capital mobility. Under this open economy interpretation, the fixed interest rate implies a fixed wage due to the constant-return-to-scale assumption.

[22] When estimating the life-cycle profiles from the PSID data, we control for time effects, as per Heathcote et al. (2005), which found no evidence for significant cohort effects.

laboratory for our quantitative analysis of income tax policy.

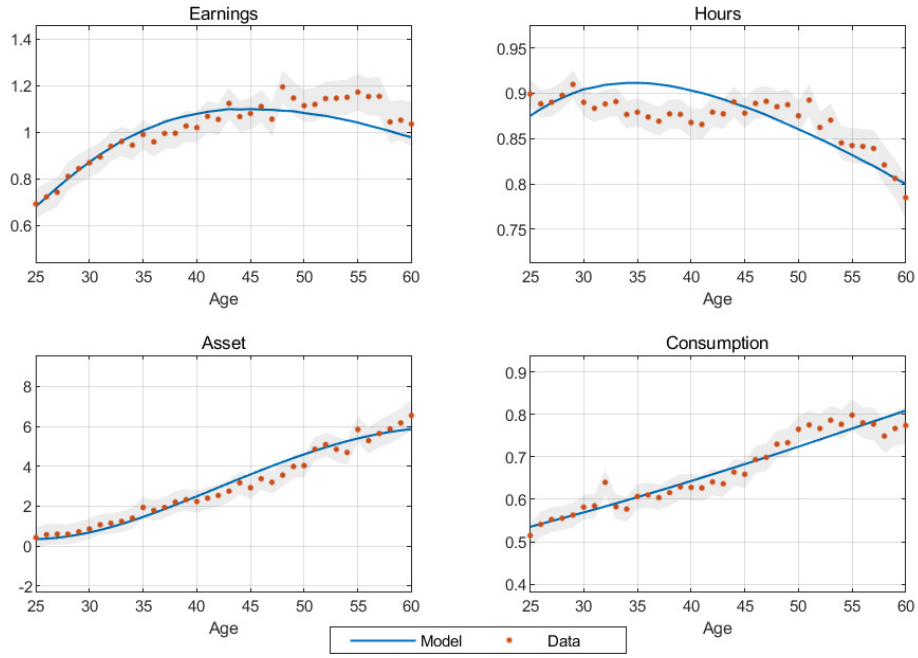

Figure 3: Model vs. Data: Life Cycles of Household Averages

Notes: This figure shows the life cycles of cross-sectional means in the benchmark model (blue solid lines) and in the PSID data (red dotted lines) together with the 95 percent confidence interval (grey bands). The consumption life cycle from the data is scaled up to match the life cycle average of consumption in the model.

Figure 3 displays the life-cycle profiles of average earnings, hours worked, assets, and consumption from age 25 to 60, for the model (solid blue lines) and the PSID data (red dotted lines with shaded 95 percent confidence intervals). In the data, average earnings show rapid growth among young households, stabilize during mid-life, and decrease near retirement. Average hours worked remain relatively stable until age 50, after which they decline notably. Average asset consistently grows until age 60, whereas average consumption shows a similar growth pattern. The model matches these empirical life-cycle profiles well.[23]

Figure 4 presents the life-cycle profiles of wage, earnings, hours worked, and consumption inequality, measured by the cross-sectional variance of natural log at each age and plotted on the same scale for ease of comparison. In the data, wage inequality rises form 0.25 at age 25 to 0.49 at age 60, driven by the accumulation of idiosyncratic wage risks. Inequality in hours

[23]Since consumption data from the PSID do not include all categories of consumption expenditures, in Figure 3, the consumption profile from the data is scaled up by a constant factor such that average consumption in the data is identical to that in the model. The focus of the comparison is hence consumption growth over life cycle. Household consumption data are normalized using the OECD-modified equivalence scale as in Kaplan (2012). Whereas raw consumption data exhibit a hump-shaped life-cycle profile, this pattern largely disappears after adjustment using the equivalence scale, which removes the effects of changes in household composition, especially variation in the number of adults and children over the life cycle.

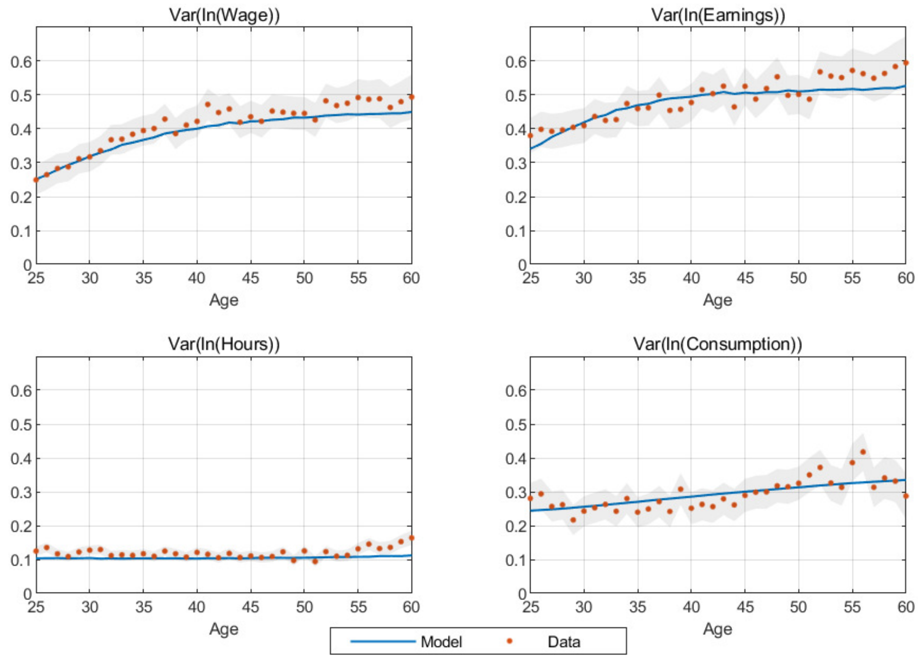

Figure 4: Model vs. Data: Life Cycles of Inequality

Notes: This figure shows the life cycles of cross-sectional variances in the benchmark model (blue solid lines) and in the PSID data (red dotted lines) together with the 95 percent confidence interval (grey bands). The life cycle of log-consumption variance in the model is shifted to match the life cycle average in the data.

worked is much smaller in comparison, and remains relatively constant between age 25 and 60. As a result, earnings inequality closely mirrors the life-cycle pattern of wage inequality, increasing from 0.38 to 0.60 between age 25 and 60. The model aligns well with these life-cycle profiles of inequality, except for some minor discrepancies near age 60. Consumption inequality in the data exhibits a gradual upward trend with age, resulting in a roughly 0.1 increase over life cycle, a pattern that is also reflected in the model.[24]

5 Economic Consequences of a Lifetime Income Tax

We now examine the welfare and economic implications of a lifetime income tax (LIT) in comparison with an annual income tax (AIT). We first quantify the potential welfare gains of AIT and LIT reforms by solving the optimal tax problem maximizing social welfare. We then investigate the mechanisms for the welfare gains of a LIT, with emphasis on improved labor efficiency through reallocation of household hours. Lastly, we discuss the life-cycle implications and transitional dynamics induced by potential reforms.

[24]Given the fact that consumption data is subject to large measurement error, we do not attempt to match the overall level of consumption dispersion in the data. Hence, in Figure 4, the life-cycle variance profile of log consumption from the model is shifted such that, *on average*, the model variances match their counterparts in the data. The key question for model validation therefore is whether the model implies empirically plausible changes in the variance over the life cycle.

5.1 The Optimal Tax Problem

We now describe the optimal income tax problem of policymakers, through which we quantify the welfare potentials of annual and lifetime income taxes. Policymakers face the classic equity-efficiency trade-off when choosing the income tax policy. On the one hand, a progressive income tax provides valuable public insurance against idiosyncratic wage risk and redistribution against ex ante heterogeneity. On the other hand, it induces efficiency losses by distorting household labor supply. Optimal policy must balance these gains and losses from progressive taxation. As explained in Section 3.3.1, income tax policy is summarized by the tax function $\widetilde{T}(y, Y, j)$ that specifies household tax liability in the current period. Depending on the type of income tax, it takes the form:

$$\widetilde{T}(y, Y, j) = \begin{cases} T(y), & \text{if annual income tax;} \\ [T(Y + \frac{y}{(1+r_d)^{j-1}}) - T(Y)](1 + r_d)^{j-1}, & \text{if lifetime income tax.} \end{cases}$$

Here y is current-year earnings, Y is accumulated lifetime earnings before current year, j is household age, and $T(\cdot)$ controls the mapping from pre-tax income to after-tax income. Following Bénabou (2002) and Heathcote et al. (2017) we parameterize the $T(\cdot)$ function as

$$T(x) = x - (1 - \tau)x^{1-\mu},$$

where (μ, τ) control the income tax progressivity and level; $1 - \mu$ is the pass-through rate of log pre-tax income to log after-tax income, and τ is the average tax rate at income level 1.

We assume that policymakers seek to maximize the expected lifetime utility of a newborn cohort in the stationary equilibrium by choosing the income tax policy, as represented by the policy parameters μ and τ. The optimal income tax problem can then be written as

$$\max_{(\mu,\tau)} \int V(\mathbf{S}; \mu, \tau) d\Phi_1(\mathbf{S}),$$

subject to the government budget constraint. Here $V(\mathbf{S}; \mu, \tau)$ is the value function of a state-$\mathbf{S}$ household under tax policy (μ, τ), and $\Phi_1(\mathbf{S})$ is the measure of newborn (i.e., age-1) state-$\mathbf{S}$ households in the economy.

Since our goal is to investigate the performance of a LIT for providing insurance and redistribution against idiosyncratic risks, we require government policy to satisfy a within-cohort budget constraint to avoid intergenerational transfers through the income tax system. That is, the within-cohort budget constraint states that the age-1 value of total government revenues collected from each cohort, discounted by the market interest rate r, must be the same as its counterpart under the status quo policy.[25]

[25] Appendix B.6 shows that if tax reforms are restricted to satisfy a within-period government budget constraint with constant government expenditure and debt (rather than insisting on constant tax revenue being

It is worth noting that in the case of a LIT, the discount rate r_d for computing lifetime income is, in principle, also a policy parameter that the government may choose. For our baseline analysis, we set $r_d = 0$ such that the LIT function $\widetilde{T}(y, Y, j)$ becomes age-independent, which has the appeal of a simpler tax policy.[26] In Section 6.1, we show that our main findings are robust to alternative choices of r_d.

Our baseline analysis also assumes that the market interest rate and hence the wage of effective labor are fixed at their status quo levels and independent of the choice of income tax policy as in a small open economy. In Section 6.2, we consider the alternative scenario of a closed economy in general equilibrium in which the interest rate and wage respond fully to changes in the tax system.

5.2 Welfare Gains of a Lifetime Income Tax

The key question of our investigation is whether a LIT can achieve higher social welfare than an AIT. To address this, we first examine the welfare effect of replacing the status quo AIT with a LIT that maintains the same progressivity and tax revenue. We then allow tax progressivity to adjust and compare the maximum achievable welfare under the optimal annual and lifetime income taxes, as determined by the optimal tax problem in Section 5.1. Table 3 presents the four tax policies considered and their associated welfare gains relative to the status quo.

Table 3: Welfare Gains from Annual and Lifetime Income Taxes

	Annual Tax		Lifetime Tax	
	Status Quo	Optimal	Status Quo μ	Optimal
Progressivity (μ)	0.137	0.233	0.137	0.267
Level (τ)	0.105	0.113	−0.434	−1.217
Level (comparable)	10.5%	11.3%	14.1%	18.2%
Avg. Tax Rate	13.7%	15.2%	15.9%	20.3%
Welfare Gain	–	0.63%	0.44%	1.60%

Notes: Welfare changes are in consumption equivalent variations as percentages of household lifetime consumption in the status quo. "Level (comparable)" is the average tax rate of a household with constant earnings equal to the status quo average in each working year. "Avg. Tax Rate" is the ratio between total labor income taxes and total labor earnings in the economy.

collected from a newborn cohort), then newborn welfare-maximizing (in stationary equilibrium) tax reforms lead to larger welfare gains, especially under a LIT. However, these gains largely stem from redistributing welfare from current old to newborn generations. An optimal policy analysis in this setting would then require taking a stance on how to weigh different generations, which we avoid by imposing the within-cohort budget constraint.

[26]Note that the choice of r_d does not affect how the government discounts tax revenues in its within-cohort budget constraint, which always uses the market interest rate r. Also, since households earnings are subject to large idiosyncratic risks, the risk-free interest rate r is not necessarily the proper choice for measuring lifetime income. See Huggett and Kaplan (2011) for more discussion on this issue.

The third column of Table 3 shows that even if the tax progressivity parameter μ remains at its status quo level, switching to a LIT that collects the same tax revenue already leads to a sizable welfare gain equivalent to 0.44% of household lifetime consumption. Note that the tax progressivity parameter μ is comparable between annual and lifetime taxes since $1 - \mu$ represents the pass-through rate from pre-tax to after-tax earnings (either annual or lifetime). On the other hand, the tax level parameter τ is not directly comparable between the two tax systems. Therefore, to compare the tax levels, we use the average tax rate faced by a hypothetical household with constant unit earnings during its working years, labeled as "Level (comparable)", which is 14.1% under the lifetime tax, compared to 10.5% under the status quo policy.[27] We also report the average tax rate, defined as the ratio between total labor income tax receipts and aggregate labor income.

When tax progressivity is optimally chosen, the advantage of a LIT becomes even more pronounced, yielding additional welfare gains equivalent to about 1% of household lifetime consumption (second and fourth columns of Table 3). Under the AIT, the optimal policy is significantly more progressive than the status quo, as indicated by the increase in tax progressivity μ from 0.137 to 0.233. This means that a 10% increase in pre-tax earnings leads to only a 7.67% increase in after-tax earnings under the optimal policy, compared to 8.63% under the status quo. Despite the substantial increase in progressivity, which suggests more redistribution across households of various income levels, the welfare gain remains modest, equivalent to 0.63% of household lifetime consumption. In comparison, the optimal LIT is more progressive than the optimal AIT (0.267 vs. 0.233) and achieves larger welfare gains, equivalent to 1.60% of household lifetime consumption.

Figure 5 shows how marginal taxs varies with current-year earnings under the AIT (blue solid lines) and the LIT with different levels of accumulated lifetime earnings (red dashed lines, green dotted lines, and black dash-dotted lines). The left panel corresponds status quo tax progressivity, whereas the right panel is for the optimal policies. The marginal tax rate rises fast with current-year earnings under the AIT, more so under the *optimal* AIT since it is more progressive than the status quo policy. In contrast, under the LIT, the marginal tax rate is almost constant with respect to current-year earnings except when accumulated lifetime earnings are low, and the progressivity of the LIT is more strongly reflected by the rising marginal tax rate with accumulated earnings. Since the progressivity of the optimal LIT is higher than in the status quo, the gaps in the marginal tax rate between different levels of accumulated earnings are bigger in the right panel.

[27] Recall that average earnings in the status quo economy is normalized to one so the hypothetical household has the status quo average earnings in each working year.

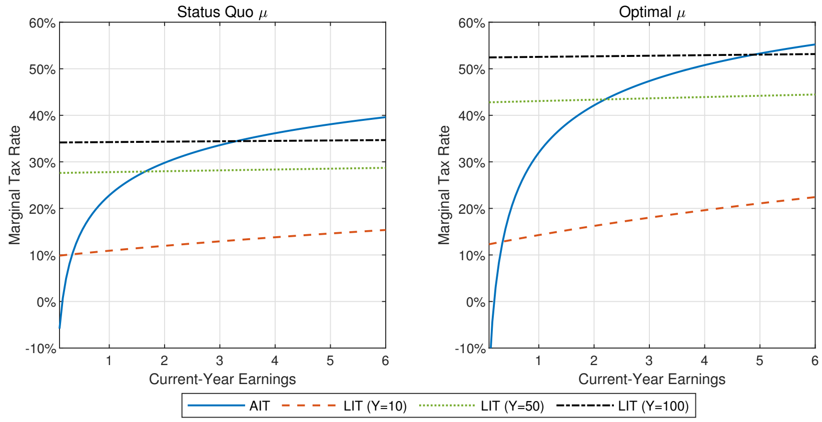

Figure 5: Marginal Tax Rate Under Annual and Lifetime Income Taxes

Notes: This figure plots the marginal tax rate on current-year earnings under AIT (blue solid lines) and LIT with accumulated lifetime earnings equal to 10, 50, and 100 income units (red dashed lines, green dotted lines, and black dash-dotted lines). In the left panel, tax progressivity μ is fixed at its status quo level 0.137, whereas the right panel refers to the optimal annual and lifetime income taxes.

5.3 Understanding the Welfare Gains

5.3.1 Aggregate and Distributional Implications

To provide intuition for the results in Table 3, Table 4 presents the changes in aggregate variables and inequality measures (i.e., variance of logs) resulting from tax reforms that replace the status quo AIT with i) the optimal AIT (first column), ii) the LIT with the status quo progressivity (second column), and iii) the optimal LIT (third column).

Table 4: Aggregate and Distributional Implications of Tax Reform

	Annual Tax	Lifetime Tax	
	Optimal	Status Quo μ	Optimal
Hours	−3.30%	−1.16%	−6.58%
Earnings	−3.69%	−0.03%	−5.13%
Labor Efficiency	−0.40%	1.14%	1.55%
Hours Inequality	−4.68%	11.98%	14.63%
Earnings Inequality	−2.45%	7.08%	9.41%
Consumption Inequality	−20.38%	0.48%	−26.07%

Notes: This table reports the changes in aggregate variables and inequality as percentages of their status quo levels, induced by tax reforms to the policy of each column. Inequality is measured by variance of logs.

Our analysis in Section 2 suggests that the primary advantage of a LIT is that it promotes a more efficient distribution of labor supply over time and across states, though at the cost of reduced consumption insurance compared to an AIT system. The results from our quantitative model fully align with this insight, as shown in the second column of Table 4. When switching from the status quo AIT to a LIT while maintaining the same tax progressivity, total hours worked and earnings decline by 1.16% and 0.03%, respectively. Since total earnings fall less than total hours, aggregate labor efficiency, defined as total earnings divided by total hours worked, rises by 1.14%. This occurs because, relative to the status quo, households work longer (shorter) hours when their wages are high (low), as reflected in increased hours and earnings inequality. On the other hand, switching to the LIT also reduces consumption insurance, resulting in higher consumption inequality. Ultimately, the benefits of improved labor efficiency outweigh the costs of worsened consumption insurance, and switching to a LIT leads to a sizable welfare gain equivalent to 0.44% of lifetime consumption.

When tax progressivity is chosen to maximize welfare, consistent with our findings in Section 2 for the two-period model, the main trade-off is between a more efficient distribution of consumption and a higher level of labor supply relative to consumption. A more progressive income tax improves consumption insurance and redistribution but depresses overall labor supply relative to consumption. Under the AIT system (first column), the optimal policy is more progressive than the status quo, and thus reduces consumption inequality substantially by 20.38% while reducing total hours worked and total earnings by 3.30% and 3.69%, respectively. Since total earnings fall more than total hours, labor efficiency is reduced by 0.40%, representing an additional cost of increased progressivity under the AIT.

In contrast, under the LIT system (third column), greater tax progressivity improves labor efficiency, providing an additional benefit of more progressive income taxation. Consequently, the optimal LIT is more progressive than the optimal AIT. It lowers hours worked and earnings further, but also reduces consumption inequality more significantly by 26.07% and improves labor efficiency by 1.55%. As a result, it achieves a higher level of welfare than the optimal AIT, with the difference amounting to about 1% of lifetime consumption.

Why does labor efficiency rise with tax progressivity under the LIT but fall under the AIT? First, when the income tax becomes more progressive, consumption inequality falls, narrowing the differences in marginal utility of consumption between high- and low-wage states. This shift in the distribution of marginal utility of consumption induces households to work more in high-wage states as their relative consumption in these states is lower under a more progressive tax policy, leading to an improvement in average labor efficiency. However, there is also a second effect of more progressive income tax: changes in marginal tax rates between the high- and low-wage states. With greater tax progressivity, the marginal tax rate rises in high-wage states and falls in low-wage states. This shift in tax rates incentivizes households to reallocate labor supply toward low-wage states, which reduces labor efficiency.

Under the AIT, because marginal taxes are more sensitive to current earnings, the second effect dominates. Therefore, the net effect of a more progressive AIT is to reduce labor efficiency. Conversely, the second effect is much weaker under the LIT because marginal tax rates respond less strongly to current earnings. As a result, the first effect dominates, and a more progressive LIT enhances labor efficiency.

5.3.2 Decomposition of Welfare Gains

Our previous discussion suggests that one key difference between the annual and lifetime income taxes is their divergent effects on labor efficiency. Not only does the LIT improve labor efficiency compared to the AIT, but this efficiency gain also increases with the progressivity of the LIT. As a result, policymakers prefer a more progressive tax system with the LIT and achieve larger welfare gains (Table 3). The more progressive LIT reduces total hours and consumption as well as consumption inequality, but raises hours inequality (Table 4). To quantify the contributions of different channels through which the LIT affects social welfare, we conduct a welfare decomposition following the method in Conesa et al. (2009) (see Appendix B.2 for the details); Table 5 contains the results.

Table 5: Decomposition of Welfare Gains

	Annual Tax	Lifetime Tax	
	Optimal	Status Quo μ	Optimal
Total Welfare Gain	0.63%	0.44%	1.60%
Consumption	−2.37%	0.37%	−2.56%
Level	−5.57%	0.42%	−6.60%
Distribution	3.39%	−0.04%	4.32%
Labor	3.07%	0.07%	4.28%
Level	2.60%	0.93%	5.10%
Distribution	0.46%	−0.86%	−0.78%

Notes: Details of the decomposition method are in Appendix B.2.

For the optimal AIT (first column), the total welfare gain of 0.63% is the combined result of welfare losses from household consumption (−2.37%) and welfare gain from household labor (3.07%). The welfare effect through consumption can be further decomposed into effects from the change in average consumption ("Level") and the change in the distribution of consumption ("Distribution") . The optimal policy attains a more equal distribution of consumption, which improves welfare by 3.39%. However, the welfare loss from the lower average consumption (−5.57%) dominates the welfare gain from reduced consumption inequality, and the net welfare effect from changes in household consumption is negative.

For the welfare effect through household labor, we similarly separate it into effects from the change in average hours worked and the change in its distribution. The optimal policy reduces average hours worked, and households enjoy more leisure which improves welfare by 2.60%. The change in the distribution of hours also improves welfare by 0.46% because household disutility from labor is convex, and hours inequality falls under the optimal AIT.

In comparison, when we switch to the LIT with the status quo progressivity (second column), most of the 0.44% welfare gain stems from rising average consumption (0.37%). The welfare gain from labor is positive but small (0.07%) because the welfare gain from more leisure (0.93%) and the welfare loss from a more dispersed hours distribution (−0.86%) largely offset each other. When we raise the progressivity of the LIT to its optimal level (third column), households enjoy more leisure and suffer less consumption inequality at the cost of lower average consumption. The net welfare effect from consumption is close to that associated with the optimal AIT, and the extra 1% total welfare gain from the optimal LIT is mostly due to the incremental welfare gain from increased leisure.

5.3.3 Insurance vs. Redistribution

A progressive income tax system provides not only insurance against ex post earnings risk but also redistribution against ex ante heterogeneity. Ex post earnings risk comprises persistent and transitory wage shocks ν and ε, and ex ante household heterogeneity includes the fixed effect of labor productivity α, the level of labor disutility ψ, and initial wealth a_0.

To separate the role of the LIT in providing insurance and redistribution, we conduct counterfactuals in which we shut down ex ante heterogeneity or ex post earnings risks. For comparison, the first two columns of Table 6 reproduce the optimal annual and lifetime income tax policies and their associated welfare gains in the economy with both types of household heterogeneity.

Table 6: Insurance vs. Redistribution

	All Heterogeneity		Only Earnings Risks		Only Ex Ante Heterogeneity	
	Annual Tax	Lifetime Tax	Annual Tax	Lifetime Tax	Annual Tax	Lifetime Tax
Progressivity (μ)	0.233	0.267	0.028	0.074	0.201	0.202
Level (τ)	0.113	−1.217	0.099	−0.159	0.117	−0.797
Level (comparable)	11.3%	18.2%	9.9%	12.0%	11.7%	15.6%
Avg. Tax Rate	15.2%	20.3%	10.3%	12.1%	11.4%	15.1%
Welfare Gain	0.63%	1.60%	0.45%	0.58%	0.20%	0.31%

The third and fourth columns report the corresponding results in the counterfactual economy with only earnings risks (i.e., without ex ante heterogeneity). The optimal annual and lifetime income taxes are still progressive, as indicated by the positive tax progressivity μ, but the degree of progressivity is lower than the status quo level (0.137). This is not surprising because: i) there is no redistribution motive anymore; and ii) wage shocks are either moderately persistent ($\rho = 0.958$) or completely transitory, and they can be insured reasonably well through private insurance channels such as precautionary savings. The welfare gains from the optimal annual and lifetime income taxes relative to the counterfactual status quo economy are 0.45% and 0.58% of lifetime consumption, respectively, which are mostly due to the rise of average consumption induced by the reduction in tax progressivity.

The optimal LIT is still more progressive than the optimal AIT since the previous labor efficiency argument still applies.

The last two columns display the results with only ex ante heterogeneity. Since ex ante heterogeneity is permanent, its welfare effect is more difficult to mitigate by household choices, giving rise to the need for government intervention. Consequently, the optimal tax polices are considerably more progressive relative to the case with only earnings risks. The welfare gains are 0.20% and 0.31% of lifetime consumption for the optimal AIT and LIT, respectively, which stem mostly from reduced consumption inequality and increased leisure under a more progressive tax system. Since without the earnings risks there is less variation in labor productivity over time and across states, the labor efficiency channel becomes weaker, and the optimal progressivity is roughly the same across the annual and lifetime income taxes. Overall, Table 6 suggests that the advantage of the LIT over the AIT is most prominent when both ex-post earnings risks and ex-ante heterogeneity are present.

5.4 Life-Cycle Implications

We now examine how the lifetime income tax affects household life cycles in the model.

5.4.1 Life Cycles of Household Averages

Figure 6 presents life-cycle profiles of average hours worked, earnings, after-tax earnings, and asset holdings under four regimes: the status quo AIT (blue solid lines), the optimal AIT (red dashed lines), the LIT with the status quo progressivity (black dash-dotted lines), and the optimal LIT (green dotted lines). The life-cycle profiles of hours worked (top-left panel) are mainly shaped by the degree of patience, the life-cycle wage profile, and tax policy. A high degree of patience (i.e., $\beta(1 + (1 - \tau_k)r) > 1$) implies that labor supply should fall with age; thus the overall downward trends in the graph. However, since the deterministic life-cycle wage profile is hump-shaped (Figure 9 in Appendix B), young households also want to delay labor supply until wages are higher to improve labor efficiency. As a result of these two forces, hours worked tend to peak earlier than the wage before declining. Switching to a LIT while maintaining the status quo progressivity reduces hours worked among old households, as higher tax rates at older ages further discourage labor supply. Under both annual and lifetime income taxes, increasing tax progressivity to the optimal level depresses labor supply at all ages, shifting the entire life-cycle hours profile downward.

Household earnings in the top-right panel largely follow the hump-shaped life-cycle wage profile, but with an earlier peak due to declining hours with age. Switching to the LIT (with status quo progressivity) leads to slightly higher (lower) earnings of young (old) households, and moving to the optimal annual or lifetime income tax lowers earnings at all ages. The bottom-left panel shows the life-cycle profiles of after-tax earnings, which differ significantly

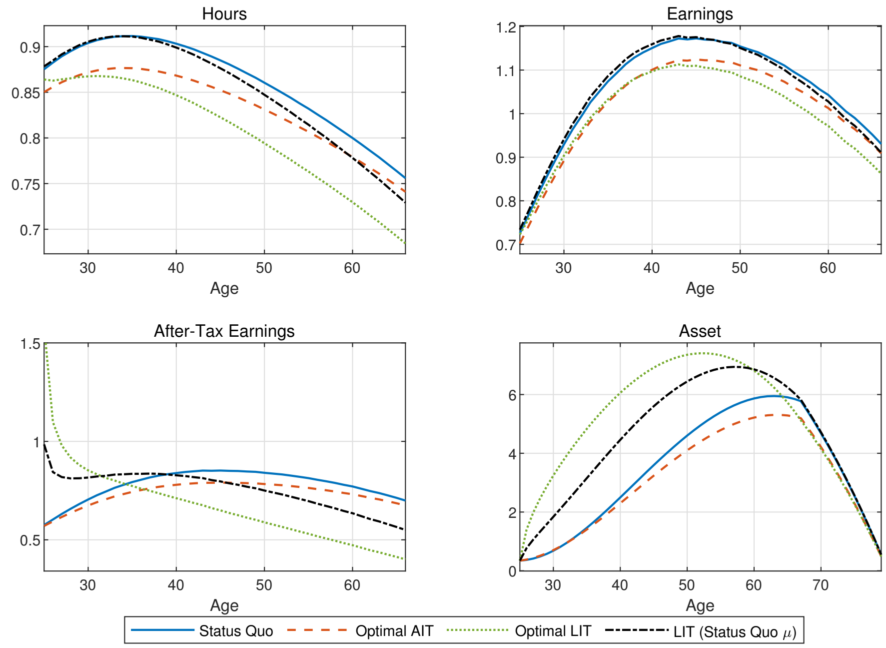

Figure 6: Life-Cycle Profiles of Household Averages

Notes: This figure plots the life-cycle means in the status quo economy (blue solid lines), under the optimal annual income tax (red dashed lines), under the optimal lifetime income tax (green dotted lines), and under the lifetime income tax with the status quo tax progressivity (black dash-dotted lines).

between annual and lifetime income taxes. With a AIT, after-tax earnings closely track household earnings. In contrast, under a progressive LIT, households receive transfers (negative taxes) from the government early in life when accumulated lifetime earnings are low. As accumulated lifetime earnings rise with age, taxes increase, causing after-tax earnings to decline over the life cycle.[28] It is worth noting that the labor supply of young households is still depressed by the LIT despite the negative tax rate, as it accounts for the fact that higher current earnings will increase future tax liabilities.

As the bottom-right panel shows, under the AIT, households accumulate wealth gradually over their working years to fund retirement consumption, but also for precautionary reasons to hedge against stochastic wage fluctuations. Household asset holdings peak near retirement as is common in life-cycle models. In contrast, under the LIT, young households accumulate substantially more assets, and household wealth peaks much earlier. Households receive transfers when young and pay higher taxes later as accumulated lifetime earnings rise with age. Consequently, they save most of these transfers to finance future taxes, which explains the rapid accumulation of wealth early in life.

[28]Redistributing income toward young households can improve welfare by relaxing borrowing constraints. However, as shown in Figure 10 of Appendix B, only a small fraction ($< 2.5\%$) of households are borrowing constrained at age 25. Therefore, this is not the main reason for the larger welfare gains from the LIT.

5.4.2 Life Cycles of Labor Efficiency and Inequality

The top-left panel of Figure 7 shows the life-cycle profiles of labor efficiency at each age divided by its counterpart in the status quo economy, under the four tax regimes. The optimal AIT reduces labor efficiency at all ages compared to the status quo, especially for households in their 30s. In contrast, the LIT improve labor efficiency throughout the life cycle, and the efficiency gains rise with age, more so under the optimal LIT. This is consistent with our theoretical findings in Section 2 that a LIT improves labor efficiency through a more efficient distribution of hours worked across contingent wage states. As wage dispersion grows with age due to the accumulation of idiosyncratic wage shocks, so does labor efficiency gain. In addition, since this efficiency gain is enhanced by the progressivity of the LIT, it rises more over the life cycle under the more progressive optimal LIT.

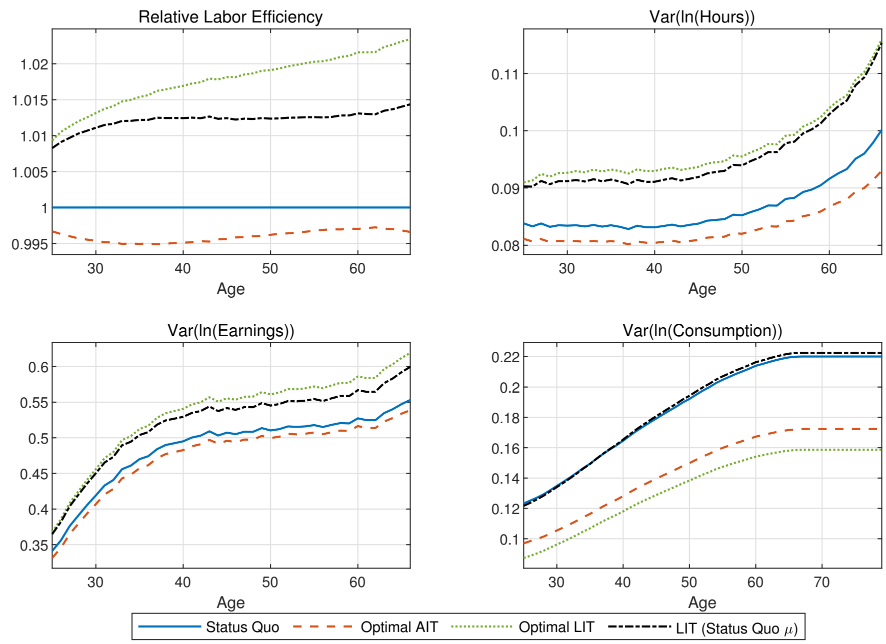

Figure 7: Life-Cycle Profiles of Labor Efficiency and Inequality

Notes: This figure plots the life-cycle profiles of relative labor efficiency and cross-sectional variances in the status quo (blue solid lines), under the optimal AIT (red dashed lines), under the optimal LIT (green dotted lines), and under the LIT with the status quo tax progressivity (black dash-dotted lines). Relative labor efficiency is labor efficiency divided by their values in the status quo economy.

The remaining panels of Figure 7 display how hours, earnings, and consumption inequality (measured by the variance of logs) evolve over the life cycle. Hours inequality (top-right panel) and earnings inequality (bottom-left panel) rise with age due to the accumulation of idiosyncratic wage shocks. Compared to the status quo economy, the optimal AIT reduces hours and earnings inequality at all ages, whereas the LIT raises them substantially throughout the life cycle. Most of these differences are due to the shift from annual to lifetime income taxation, and raising the progressivity of the LIT further to its optimal level has small effects. Consumption inequality (bottom-right panel) also increases over the life cycle as the accumulation of idiosyncratic wage shocks leads to greater dispersion within each cohort. After retirement, as wage risk disappear, consumption inequality stabilizes. Consistent with our findings in Section 2, switching to the LIT with the same progressivity as the status quo results in higher consumption inequality, particularly among old households, although the increase is small. Both the optimal annual and lifetime income taxes are more progressive than the status quo policy, thereby reducing consumption inequality significantly compared to the status quo. The reduction is more pronounced under the optimal LIT, as it is more progressive than the optimal AIT.

5.5 Transition to the Optimal Stationary Equilibrium

The optimal policies reported in Table 3 maximize social welfare in stationary equilibrium, and the LIT outperforms an AIT in terms of maximum welfare gain by about 1% of household lifetime consumption. However, what are the welfare consequences of these tax reforms to households during the transition from the status quo economy to the optimal stationary equilibrium? To understand these, we compute the equilibrium transition induced by the optimal tax reforms in Table 3. Suppose that the economy is in stationary equilibrium with the status quo AIT policy. Then at time $t = 0$, a permanent change in income tax policy occurs (i.e., switching to the optimal annual or lifetime income tax), and the economy evolves endogenously towards that stationary equilibrium. We label different generations of households by the time of their birth; generation x is born at time $t = x$. At the time of the tax reform, we consider two alternative scenarios: i) the new policy is only applicable to new households (i.e., current and future new-born households), and households born before the tax reform are still subject to the original status quo policy; or ii) all current and future households are subject to the new tax policy.

As mentioned in Section 5.1, to focus on the insurance and redistribution role of income taxes, we impose a within-cohort government budget constraint when solving for the optimal policy. This guarantees that the present-value of total tax revenues collected from each cohort is the same between the status quo and the optimal policies. However, this also implies that the amount of government debt must differ between the status quo and the optimal stationary equilibrium to simultaneously satisfy the government period budget constraint. In Appendix B.3, we show that if the tax reform is only applicable to new households, and the within-cohort government budget constraint is satisfied, then the level of government debt will evolve endogenously following the government period budget constraint along the transition and eventually converge to a sustainable level in the new stationary equilibrium.

The top-left panel of Figure 8 presents the welfare effects of the annual and lifetime tax reforms for different generations of households when the new policy is only applicable to new households. Without changes in factor prices (i.e., interest rate and wage of effective labor), current households (generations $x < 0$) are completely insulated from the influence of tax reform. In contrast, new generations immediately enjoy the full benefit of the tax reform, obtaining the welfare gain of the optimal stationary equilibrium, which is larger under the LIT than under the AIT by about 1% of lifetime consumption. In this sense, our previous conclusion that the LIT outperforms the AIT remains valid when taking into account transitional dynamics. As the top-right panel shows, under both policies government debt gradually increases along the transition and eventually stabilizes at a higher level (which is much more substantial in the case of the optimal lifetime income tax).

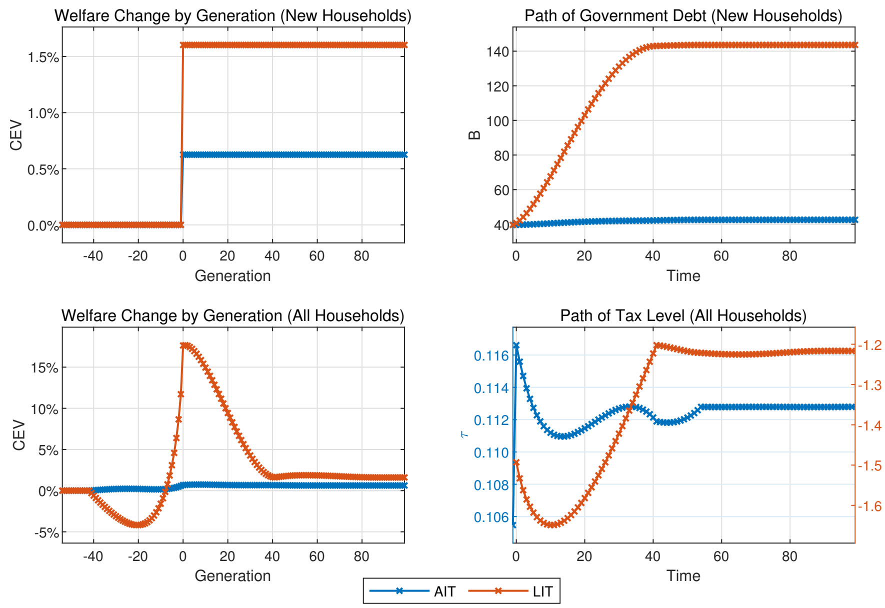

Figure 8: Transition to the Optimal Stationary Equilibrium

Notes: This figure shows the transitions from the status quo to the optimal steady state with annual and lifetime income taxes, assuming that the new policy only applies to new households (top panels) or all households (bottom panels). The left panels display the welfare effects of tax reforms on different generations, the top-right panel plots the paths of government debt, and the bottom-right panel plots the paths of the tax level τ that balance the government budget period-by-period. The tax reform occurs at $t = 0$.

Suppose now that we subject all current and future households to the new tax policy after the reform. Then the adjustment of government debt alone is no longer sufficient for a feasible transition towards the optimal stationary equilibrium because the level of government debt would diverge. Therefore, in this scenario, we also allow the tax level τ to vary over time to balance the government period budget constraint along the transition, subject to the restriction that it eventually converges to the tax level of the optimal policy, insuring that the economy still converges to the optimal stationary equilibrium. For comparability, we set the paths of government debt to be the same as those displayed in the top-right panel.[29]

[29]There are in principle infinitely many combinations of the paths of government debt and income tax

For the AIT reform, the bottom-left panel of Figure 8 shows that current generations (generation $x < 0$) are no longer immune to the influence of the tax reform: they benefit from the reform but with lower welfare gains compared to future generations.[30] The bottom-right panel shows that the AIT level jumps up immediately after the tax reform before falling gradually to the long-run optimal level. For the LIT reform, the bottom-left panel shows that the current middle-aged and old working generations suffer significant welfare losses upon the tax reform, whereas the current young generations and generations born within 30 years after the tax reform enjoy even more substantial welfare gains. The level of the LIT level is low at the start of the transition and gradually rises over time (bottom-right panel).

6 Robustness Analysis

6.1 Effects of Discount Rate for Calculating Lifetime Earnings

To implement a LIT, the government needs to choose a discount rate r_d for calculating lifetime earnings. We now explore the effects of this choice for the performance of the LIT. First, the choice of discount rate r_d only matters for the calculation of tax liability in the lifetime income tax function $\widetilde{T}(y, Y, j)$. It does not affect how households and the government discount future income and revenues in their budget constraints. There are three intuitive choices for r_d: zero, the pre-tax interest rate r, or the after-tax interest rate $(1 - \tau_k)r$. In our baseline, we set r_d to zero such that the lifetime income tax function $\widetilde{T}(y, Y, j)$ no longer includes age explicitly. The pre-tax interest rate r is the discount rate faced by the government, and the after-tax interest rate $(1-\tau_k)r$ is the private discount rate of households.

Table 7 reports the effects of r_d on optimal tax policies and the associated welfare gains. For the AIT (first two columns), since r_d does not enter the income tax function, it is nearly irrelevant.[31] For the LIT (last two columns), a higher r_d lowers the welfare gain from adopting the LIT: when r_d increases from zero to the pre-tax interest rate, the welfare gain from the optimal LIT falls from 1.60% to 1.06% of lifetime consumption. Nevertheless, the welfare gains remain larger than in the optimal AIT. Likewise, switching to a LIT with the status quo progressivity still generates sizable welfare gains compared to the status quo AIT.

A lower discount rate r_d reduces the relative weights on early-life earnings in the calculation of lifetime earnings for tax purposes, leading to lower tax rates for young households. This introduces intertemporal distortions that reduce labor supply of old households. As discussed in Section 2, such distortions may improve consumption insurance by mitigating

levels that balance the government period budget constraints along the transition.

[30]The plotted welfare change is the average across all households of the same generation. Therefore, a positive welfare gain does not imply that *all* households within that generation are better off.

[31]The small effect of r_d comes from the calculation of average earnings $\bar{y}$ for retirement benefits in (18).

the impact of wage risks, which are more pronounced later in life due to the accumulation of idiosyncratic wage shocks. This explains why setting a zero discount rate for the LIT achieves higher welfare gains than using either the pre- or after-tax interest rate. While adopting the pre- or after-tax interest rate enhances labor efficiency more, it provides less consumption insurance, resulting in lower welfare.

Table 7: Effects of Discount Rate for Lifetime Earnings (r_d)

		Annual Tax		Lifetime Tax	
Case		Status Quo	Optimal	Status Quo μ	Optimal
$r_d = 0$	Progressivity (μ)	0.137	0.233	0.137	0.267
	Level (τ)	0.105	0.113	−0.434	−1.217
	Welfare Gain	–	0.63%	0.44%	1.60%
$r_d = (1 - \tau_k)r$	Progressivity (μ)	0.137	0.234	0.137	0.263
	Level (τ)	0.105	0.113	−0.401	−1.102
	Welfare Gain	–	0.64%	0.34%	1.27%
$r_d = r$	Progressivity (μ)	0.137	0.235	0.137	0.256
	Level (τ)	0.105	0.113	−0.386	−1.012
	Welfare Gain	–	0.63%	0.30%	1.06%

6.2 Accounting for General Equilibrium Effects

Our baseline analysis assumes that the interest rate and the wage rate are not affected by adjustments of income tax policy. We now extend our analysis to general equilibrium where the interest rate and wage are determined by domestic capital and labor markets clearing and thus influenced by income tax policy.[32] Table 8 reports the results.[33] Accounting for general equilibrium leads to substantially more progressive optimal policies. Similar to our baseline results, the optimal LIT is still slightly more progressive than the optimal AIT (Panel A). For both tax systems, general equilibrium effects raise the wage and lower the interest rate, with magnitudes of changes that are close for the two types of income taxes (Panel B).

The optimal income taxes still reduce total hours and earnings, but compared to our baseline results, total earnings fall less due to the higher wage level in general equilibrium (Panel C). For the same reason, aggregate labor efficiency improves under both the annual and lifetime income taxes. However, labor efficiency grows less than the wage under the AIT, but more under the LIT. Therefore, consistent with our previous findings, the optimal annual (lifetime) income tax still induces a shift in the distribution of hours that decreases (increases) aggregate efficiency, and hours- and earnings inequality. Because the optimal policies in general equilibrium are more progressive, consumption inequality falls more than

[32] Since we impose a within-cohort government budget constraint when solving for optimal policy, the level of government debt must adjust to balance the government period budget in stationary equilibrium.

[33] Appendix B.4 discusses the life-cycle implications of tax reforms with general equilibrium effects.

Table 8: Optimal Income Tax in General Equilibrium

	Annual Tax	Lifetime Tax		Annual Tax	Lifetime Tax
A. Optimal Income Tax			*B. General Equilibrium Effects*		
Progressivity (μ)	0.334	0.351	Wage	6.46%	6.41%
Level (τ)	0.073	−2.266	Interest Rate[a]	−1.75*pp*	−1.73*pp*
Level (comparable)	7.3%	12.2%			
Avg. Tax Rate	13.1%	16.0%			
C. Aggregate and Distributional Implications			*D. Welfare Gains and Decomposition*		
Hours	−7.49%	−10.09%	Total Welfare Gain	7.85%	8.87%
Earnings	−2.14%	−2.23%	Consumption	0.71%	0.97%
Labor Efficiency	5.77%	8.74%	Level	−8.18%	−8.17%
			Distribution	9.69%	9.95%
Hours Inequality	−11.12%	7.96%	Labor	7.09%	7.83%
Earnings Inequality	−4.74%	10.36%	Level	5.87%	7.82%
Consumption Inequality	−47.20%	−48.22%	Distribution	1.15%	0.00%

Notes: [a] The number reported is the percentage-point change in interest rate.

in our baseline results. The welfare gains from the optimal annual and lifetime income taxes are substantially larger in general equilibrium, but as in our baseline analysis, the LIT still outperforms the AIT by about 1% in terms of welfare gains (Panel D). And most of this extra welfare gain from the optimal LIT is again due to a greater increase in leisure.[34]

In summary, the larger welfare gains in Panel D of Table 8 mostly stem from the direct and indirect effects of factor price adjustments, while the welfare advantage of the optimal LIT relative to the optimal AIT is mainly driven by the direct effects of tax policy already present in partial equilibrium, justifying our choice of this specification as our benchmark.

7 Conclusion

In this paper, we have explored whether an income tax system based on household lifetime earnings is superior to the prevailing annual income tax system adopted by most countries. This inquiry arises from the fundamental observation that lifetime earnings provide a potentially more precise indicator of household welfare, making it a more suitable base for welfare redistribution. Our quantitative analysis, based on an incomplete-markets life-cycle model of heterogeneous households calibrated to the U.S. economy, yields an affirmative answer. Switching to lifetime income tax promotes aggregate labor efficiency by inducing a more efficient distribution of hours worked. A more progressive lifetime income tax further enhances this benefit, whereas a more progressive annual income tax has the opposite effect. Consequently, the optimal lifetime income tax is more progressive and achieves larger welfare gains than the optimal annual income tax.

[34] In Appendix B.5 we report step-by-step welfare changes from the status quo economy to the general equilibrium under the optimal annual and lifetime income taxes.

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Online Appendix

Taxes on Lifetime Income: A Good Idea?

Dirk Krueger and Chunzan Wu

A Proofs for the Two-Period Model

A.1 Proof of Proposition 1

The Lagrange function for the social planner's problem is

$$\mathcal{L} = U(c_1, l_1) + \mathbf{E}\{U(c_2, l_2)\} - \lambda[c_1 + \mathbf{E}\{c_2\} - w_1 l_1 - \mathbf{E}\{w_2 l_2\}],$$

where λ is the multiplier on the resource constraint. Note that c_2 and l_2 are all contingent on the second period state. The first order conditions are then

$$\begin{aligned} c_1 : &\quad U_c(c_1, l_1) = \lambda, \\ c_2(s) : &\quad U_c(c_2(s), l_2(s)) = \lambda, \\ l_1 : &\quad U_l(c_1, l_1) = -\lambda w_1, \\ l_2(s) : &\quad U_l(c_2(s), l_2(s)) = -\lambda w_2(s), \end{aligned}$$

together with the resource constraint (4).

Combining the first order conditions w.r.t. c_1 and $c_2(s)$ to eliminate λ, we get the Euler equation (5). Using the first order conditions w.r.t. c_1 and $c_2(s)$ to substitute λ in the first order conditions w.r.t. l_1 and $l_2(s)$, respectively, we have the intratemporal optimality conditions (6). Finally, combining the first order conditions w.r.t. l_1 and $l_2(s)$ to eliminate λ, we get (7) and (8).

A.2 Proof of Proposition 2

Note that in partial equilibrium with exogenous wage and interest rate and no government, the only equilibrium conditions are those associated with the household utility maximization. The Lagrange function for the household's problem is

$$\mathcal{L} = U(c_1, l_1) + \mathbf{E}\{U(c_2(s), l_2(s))\} - \lambda_1(c_1 + a - w_1 l_1) - \mathbf{E}\{\lambda_2(s)[c_2(s) - a - w_2(s) l_2(s)]\},$$

where λ_1 and $\lambda_2(s)$ are multipliers on the first and second period budget constraints. The first order conditions are then

$$\begin{aligned} c_1 : &\quad U_c(c_1, l_1) = \lambda_1, \\ c_2(s) : &\quad U_c(c_2(s), l_2(s)) = \lambda_2(s), \\ l_1 : &\quad U_l(c_1, l_1) = -\lambda_1 w_1, \end{aligned}$$

$$\begin{aligned} l_2(s): &\quad U_l(c_2(s), l_2(s)) = -\lambda_2(s) w_2(s), \\ a: &\quad \lambda_1 = \mathbf{E}\{\lambda_2(s)\}, \end{aligned}$$

together with the first and second period budget constraints.

Use the conditions w.r.t. c_1 and $c_2(s)$ to substitute λ_1 and $\lambda_2(s)$ in the condition w.r.t. a, and we get the Euler equation (9). Use the first order conditions w.r.t. c_1 and $c_2(s)$ to substitute λ_1 and $\lambda_2(s)$ in the first order conditions w.r.t. l_1 and $l_2(s)$, respectively, and we have the intratemporal optimality conditions (10). Use the conditions w.r.t. l_1 and $l_2(s)$ to substitute λ_1 and $\lambda_2(s)$ in the condition w.r.t. a, and we get (12). Use the the condition w.r.t $c_2(s)$ to substitute $\lambda_2(s)$ in the condition w.r.t. $l_2(s)$, and then take the ratio of the resulting equation between any two states s' and s, and we get (13).

A.3 Proof of Proposition 3

The Ramsey equilibrium consists of the optimality conditions of households and the government budget constraint. The Lagrange function for the household's optimization problem is

$$\mathcal{L} = U(c_1, l_1) + \mathbf{E}\{U(c_2, l_2)\} - \lambda_1[c_1 + a - w_1 l_1 + T(w_1 l_1)] - \mathbf{E}\{\lambda_2[c_2 - a - w_2 l_2 + \widetilde{T}(w_1 l_1, w_2 l_1)]\},$$

where λ_1 and λ_2 are multipliers on the first and second period budget constraints. Note that c_2, l_2, and λ_2 are all contingent on the second period state s, whereas a is state-uncontingent. The first order conditions are then

$$c_1: \quad U_c(c_1, l_1) = \lambda_1, \tag{22}$$

$$c_2: \quad U_c(c_2, l_2) = \lambda_2, \tag{23}$$

$$l_1: \quad -U_l(c_1, l_1) = \lambda_1 w_1[1 - T'(w_1 l_1)] - \mathbf{E}\{\lambda_2 w_1 \widetilde{T}_1(w_1 l_1, w_2 l_2)\}, \tag{24}$$

$$l_2: \quad -U_l(c_2, l_2) = \lambda_2 w_2[1 - \widetilde{T}_2(w_1 l_1, w_2 l_2)], \tag{25}$$

$$a: \quad \lambda_1 = \mathbf{E}\{\lambda_2\}, \tag{26}$$

together with the first and second period budget constraints.

A.3.1 Annual Income Tax (AIT)

Under annual income tax,

$$\widetilde{T}(w_1 l_1, w_2 l_2) = T(w_2 l_2).$$

$\Rightarrow$

$$\begin{aligned} \widetilde{T}_1(w_1 l_1, w_2 l_2) &= 0, \\ \widetilde{T}_2(w_1 l_1, w_2 l_2) &= T'(w_2 l_2). \end{aligned}$$

Use (24) and (25) to eliminate λ_1 and λ_2 in (26), and we have the intertemporal condition:

$$\frac{U_l(c_1, l_1)}{w_1[1 - T'(w_1 l_1)]} = \mathbf{E}\left\{\frac{U_l(c_2, l_2)}{w_2[1 - T'(w_2 l_2)]}\right\}.$$

Use (23) to eliminate λ_2 in (25), then take the ratio across two possible second period states s' and s, and we have

$$\frac{U_l(c_2(s'), l_2(s'))}{U_l(c_2(s), l_2(s))} = \left[\frac{1 - T'(w_2(s')l_2(s'))}{1 - T'(w_2(s)l_2(s))}\right] \left[\frac{U_c(c_2(s'), l_2(s'))}{U_c(c_2(s), l_2(s))}\right] \left[\frac{w_2(s')}{w_2(s)}\right].$$

A.3.2 Lifetime Income Tax (LIT)

Under lifetime income tax,

$$\widetilde{T}(w_1 l_1, w_2 l_2) = T(w_1 l_1 + w_2 l_2) - T(w_1 l_1).$$

$\Rightarrow$

$$\begin{aligned}\widetilde{T}_1(w_1 l_1, w_2 l_2) &= T'(w_1 l_1 + w_2 l_2) - T'(w_1 l_1),\\ \widetilde{T}_2(w_1 l_1, w_2 l_2) &= T'(w_1 l_1 + w_2 l_2).\end{aligned}$$

(24) then becomes

$$\begin{aligned}-U_l(c_1, l_1) &= \lambda_1 w_1[1 - T'(w_1 l_1)] - \mathbf{E}\{\lambda_2 w_1[T'(w_1 l_1 + w_2 l_2) - T'(w_1 l_1)]\}\\ &= \lambda_1 w_1[1 - T'(w_1 l_1)] - \mathbf{E}\{\lambda_2 w_1[-1 + T'(w_1 l_1 + w_2 l_2) + 1 - T'(w_1 l_1)]\}\\ &= w_1(\lambda_1 - \mathbf{E}\{\lambda_2\})[1 - T'(w_1 l_1)] + w_1 \mathbf{E}\{\lambda_2[1 - T'(w_1 l_1 + w_2 l_2)]\})\end{aligned}$$

Use (26) to eliminate $\lambda_1 - \mathbf{E}\{\lambda_2\}$, and (25) to eliminate $\lambda_2[1 - T'(w_1 l_1 + w_2 l_2)]$, then divide both sides by $-w_1$, and we have the intertemporal condition:

$$\frac{U_l(c_1, l_1)}{w_1} = \mathbf{E}\left\{\frac{U_l(c_2, l_2)}{w_2}\right\}.$$

Use (23) to eliminate λ_2 in (25), then take the ratio across two possible second period states s' and s, and we have

$$\frac{U_l(c_2(s'), l_2(s'))}{U_l(c_2(s), l_2(s))} = \left[\frac{1 - T'(w_1 l_1 + w_2(s')l_2(s'))}{1 - T'(w_1 l_1 + w_2(s)l_2(s))}\right] \left[\frac{U_c(c_2(s'), l_2(s'))}{U_c(c_2(s), l_2(s))}\right] \left[\frac{w_2(s')}{w_2(s)}\right].$$

A.4 Effect of τ: Additively Separable Preferences and HSV Tax Function

We now show that under the additional assumptions about the two-period model in Section 2.6, a change in the tax level parameter τ alone does not affect the relative distribution of consumption or labor over time and across states for either annual or lifetime income taxes, but only shifts the overall levels of consumption and labor. As a result, all wedges defined in Table 1, except the consumption-labor wedge, remain unaffected.

Proposition 4. *Holding the income tax type fixed (either annual or lifetime income tax), let* $\{\bar{c}_1, \bar{l}_1, [\bar{c}_2(s), \bar{l}_2(s)]_{s\in S}\}$ *denote the household's optimal choices under a tax policy with level* $\tau = 0$ *and progressivity* μ*. Then under a tax policy characterized by* τ *and* μ*, the household's* *optimal choices satisfy*

$$\frac{c_1}{\bar{c}_1} = \frac{c_2(s)}{\bar{c}_2(s)} = \kappa_c, \ \forall s \in S,$$
$$\frac{l_1}{\bar{l}_1} = \frac{l_2(s)}{\bar{l}_2(s)} = \kappa_l, \ \forall s \in S,$$

where

$$\kappa_c = (1-\tau)^{1+\frac{(1-\sigma)(1-\mu)}{\mu+1/\eta+(1-\mu)\sigma}},$$
$$\kappa_l = (1-\tau)^{\frac{1-\sigma}{\mu+1/\eta+(1-\mu)\sigma}}.$$

Proof.

Annual income tax. The optimal choices under (τ, μ) are characterized by

$$c_1{}^{-\sigma} = \mathbf{E}\{(c_2(s))^{-\sigma}\},$$
$$c_1{}^{-\sigma}(1-\tau)(1-\mu)(w_1 l_1)^{-\mu} w_1 = \psi l_1^{1/\eta},$$
$$[c_2(s)]^{-\sigma}(1-\tau)(1-\mu)[w_2(s)l_2(s)]^{-\mu} w_2(s) = \psi [l_2(s)]^{1/\eta}, \ \forall s \in S,$$
$$c_1 + c_2(s) = (1-\tau)(w_1 l_1)^{1-\mu} + (1-\tau)[w_2(s)l_2(s)]^{1-\mu}, \ \forall s \in S.$$

Plug in the proposed solution, and we have

$$\kappa_c^{-\sigma}(1-\tau) = \kappa_l^{\mu+1/\eta},$$
$$\kappa_c = (1-\tau)\kappa_l^{1-\mu}.$$

$\Rightarrow$

$$\kappa_c = (1-\tau)^{1+\frac{(1-\sigma)(1-\mu)}{\mu+1/\eta+(1-\mu)\sigma}},$$
$$\kappa_l = (1-\tau)^{\frac{1-\sigma}{\mu+1/\eta+(1-\mu)\sigma}}.$$

Lifetime income tax. The optimal choices under (τ, μ) are characterized by

$$c_1{}^{-\sigma} = \mathbf{E}\{(c_2(s))^{-\sigma}\},$$
$$\mathbf{E}\left\{[c_2(s)]^{-\sigma}(1-\tau)(1-\mu)[w_1 l_1 + w_2(s)l_2(s)]^{-\mu}\right\} w_1 = \psi l_1^{1/\eta},$$
$$[c_2(s)]^{-\sigma}(1-\tau)(1-\mu)[w_1 l_1 + w_2(s)l_2(s)]^{-\mu} w_2(s) = \psi [l_2(s)]^{1/\eta}, \ \forall s \in S,$$
$$c_1 + c_2(s) = (1-\tau)[w_1 l_1 + w_2(s)l_2(s)]^{1-\mu}, \ \forall s \in S.$$

Plug in the proposed solution, and we have

$$\kappa_c^{-\sigma}(1-\tau) = \kappa_l^{\mu+1/\eta},$$
$$\kappa_c = (1-\tau)\kappa_l^{1-\mu}.$$

Note that these conditions are the same as those for annual income tax. Therefore, κ_c and κ_l are the same for both annual and lifetime income taxes.

□

Corollary 1. *For both annual and lifetime income taxes, the intertemporal and dispersion wedges of consumption and labor remain invariant with respect to the tax level parameter* τ*. Only the consumption-labor wedge and the overall levels of consumption and labor are affected.*

B Supplementary Results for Quantitative Analysis

In this section, we provide supplementary results to the quantitative analysis in the main text.

B.1 Wage Profile and Share of Borrowing Constrained

Figure 9 displays the deterministic log-wage trends over the life cycle, estimated from the PSID data. Figure 10 presents the share of borrowing constrained households in the status quo economy.

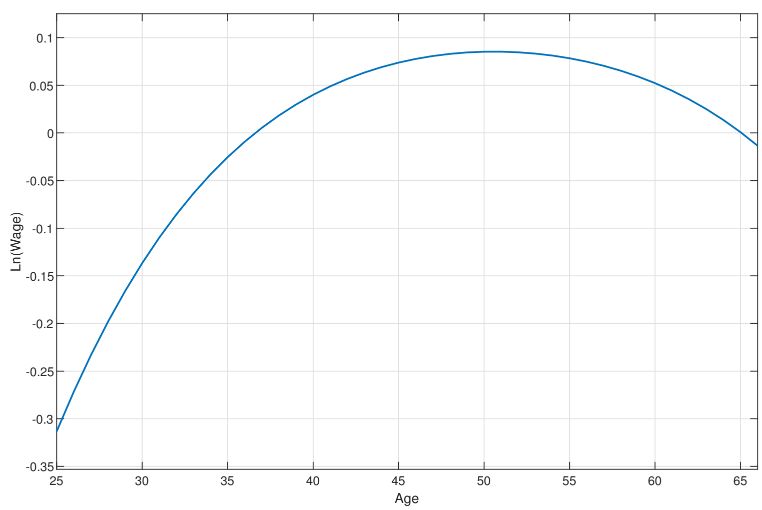

Figure 9: Life-Cycle Wage Trend

Notes: This figure plots the deterministic log-wage trend over household life cycle estimated from the PSID data.

B.2 Welfare Decomposition

In this section, we explain how welfare changes in consumption-equivalent variations (CEV) and the decomposition of welfare changes into level and distribution effects of consumption and labor are calculated in the main text, for which we follow the method in Conesa et al. (2009). The notations are independent from the main text or other sections of the appendix.

Consider, for example, an income tax change in the model economy. Let $\mathbf{c}^0$ and $\mathbf{h}^0$ denote the state-contingent plan of household consumption and labor supply before the tax reform,

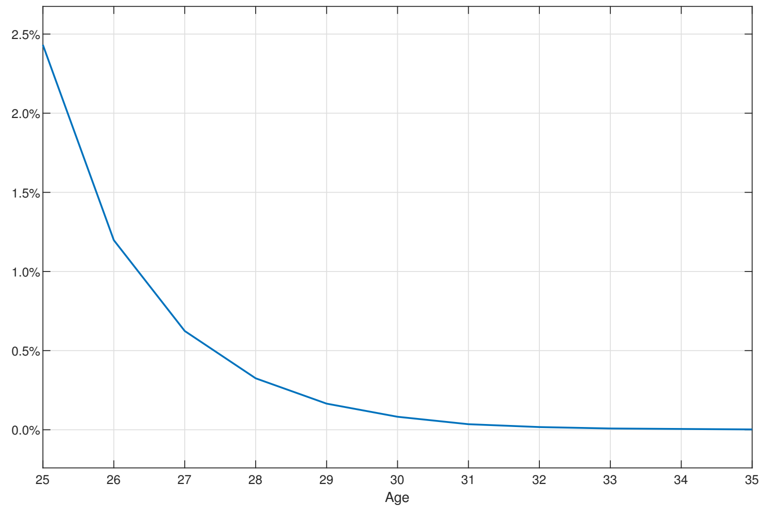

Figure 10: Share of Borrowing Constrained Households

Notes: This figure plots the percentage of borrowing constrained households in the status quo economy.

and let $W(\mathbf{c}^0, \mathbf{h}^0)$ denote social welfare under this state-contingent plan. After the tax reform, the corresponding state-contingent plan is denoted by $\mathbf{c}^1$ and $\mathbf{h}^1$, and the social welfare is $W(\mathbf{c}^1, \mathbf{h}^1)$.

The welfare effect of this tax change in consumption-equivalent variation, CEV, is defined by the following equation:

$$W((1 + CEV)\mathbf{c}^0, \mathbf{h}^0) = W(\mathbf{c}^1, \mathbf{h}^1).$$

That is, CEV is the percentage change of lifetime consumption (i.e., consumption at all ages and all states) required to generate a change in social welfare equal to that induced by the tax reform. If CEV is positive (negative), the tax reform is welfare-improving (welfare-reducing).

We can decompose CEV into components stemming from the change in consumption and the change in labor. The welfare change due to consumption change, CEV_C, is defined by the following equation:

$$W((1 + CEV_C)\mathbf{c}^0, \mathbf{h}^0) = W(\mathbf{c}^1, \mathbf{h}^0).$$

And the welfare change due to changes in labor, CEV_L, is defined by:

$$W((1 + CEV_L)(1 + CEV_C)\mathbf{c}^0, \mathbf{h}^0) = W(\mathbf{c}^1, \mathbf{h}^1).$$

Therefore,

$$(1 + CEV) = (1 + CEV_C)(1 + CEV_L).$$

Furthermore, the welfare effect of consumption change can itself be divided into a part that is due to the change in average consumption, and a part that reflects the change in the distribution of consumption over life cycle and across idiosyncratic states. Let $\bar{\mathbf{c}}^0$ and $\bar{\mathbf{c}}^1$

denote the average household consumption before and after the tax reform, then the welfare change due to the change in consumption level, CEV_{CL}, is define by

$$W((1+CEV_{CL})\mathbf{c}^0, \mathbf{h}^0) = W(\frac{\bar{\mathbf{c}}^1}{\bar{\mathbf{c}}^0}\mathbf{c}^0, \mathbf{h}^0),$$

i.e., $CEV_{CL} = \bar{\mathbf{c}}^1/\bar{\mathbf{c}}^0 - 1$, which is the percentage change of average household consumption due to the tax change. The welfare change due to the change in the distribution of consumption, CEV_{CD}, is defined by

$$W((1+CEV_{CD})(1+CEV_{CL})\mathbf{c}^0, \mathbf{h}^0) = W(\mathbf{c}^1, \mathbf{h}^0).$$

And hence we have,

$$(1+CEV_C) = (1+CEV_{CD})(1+CEV_{CL}).$$

Similarly, for the labor change, we can define CEV_{HL} and CEV_{HD} by

$$W((1+CEV_{HL})(1+CEV_C)\mathbf{c}^0, \mathbf{h}^0) = W(\mathbf{c}^1, \frac{\bar{\mathbf{h}}^1}{\bar{\mathbf{h}}^0}\mathbf{h}^0),$$

$$W((1+CEV_{HD})(1+CEV_{HL})(1+CEV_C)\mathbf{c}^0, \mathbf{h}^0) = W(\mathbf{c}^1, \mathbf{h}^1),$$

where $\bar{\mathbf{h}}^0$ and $\bar{\mathbf{h}}^1$ are the average household labor before and after the tax reform, and we have

$$(1+CEV_H) = (1+CEV_{HD})(1+CEV_{HL}).$$

B.3 Government Debt in Transition

In this section, we consider the dynamics of government debt after a permanent tax reform as described in Section 5.5. We show that if i) the new policy is only applicable to new households, ii) both the original and new tax policies satisfy the within-cohort government budget constraint, and iii) factor prices (i.e., interest rate and wage) are fixed, then the level of government debt will converge automatically to the sustainable level at the new stationary equilibrium. In other words, such tax reform is feasible.

Let B_t denote the level of government debt at the start of period t, then the period-t government budget constraint can be written as:

$$B_{t+1} = (1+r)B_t + G - X_t,$$

where X_t represents the net revenue of government in period t, G is government expenditures, and r is the interest rate. Differentiating both sides of the equation with respect to time t, we have

$$\Delta B_{t+1} = (1+r)\Delta B_t - \Delta X_t. \tag{27}$$

Suppose that the tax reform occurs at the beginning of period 0, and the new policy is only applied to new households, i.e., households born at $t \geq 0$. Let $\bar{x}_j$ and $\hat{x}_j$, $j = 1, \ldots, J$, denote the government's net revenue from age-j households under the original and new tax policies, respectively. Because a new cohort of households enter the economy in each period, and they live for J periods, we have

$$X_t = \begin{cases} \sum_{j=1}^{J} \bar{x}_j, & \text{if } t < 0, \\ \sum_{j=1}^{J} \hat{x}_j, & \text{if } t \geq J-1, \end{cases}$$

and

$$\Delta X_t = \begin{cases} 0, & \text{if } t < 0, \\ \hat{x}_{t+1} - \bar{x}_{t+1}, & \text{if } 0 \leq t \leq J-1, \\ 0, & \text{if } t > J-1. \end{cases}$$

Since the economy is at the original stationary equilibrium before period 0 with constant government debt, $\Delta B_0 = 0$. From equation (27), we then have

$$\begin{aligned}
\Delta B_1 &= -\Delta X_0 = \bar{x}_1 - \hat{x}_1, \\
\Delta B_2 &= (1+r)(\bar{x}_1 - \hat{x}_1) + (\bar{x}_2 - \hat{x}_2), \\
&\vdots \\
\Delta B_J &= \sum_{j=1}^{J} (1+r)^{J-j} (\bar{x}_j - \hat{x}_j) \\
&= (1+r)^{J+1} \left[\left(\sum_{j=1}^{J} \frac{\bar{x}_j}{(1+r)^{j-1}} \right) - \left(\sum_{j=1}^{J} \frac{\hat{x}_j}{(1+r)^{j-1}} \right) \right].
\end{aligned}$$

Because both the original and new policies satisfy the same within-cohort budget constraint, we have

$$\sum_{j=1}^{J} \frac{\bar{x}_j}{(1+r)^{j-1}} = \sum_{j=1}^{J} \frac{\hat{x}_j}{(1+r)^{j-1}},$$

which then implies

$$\Delta B_J = 0,$$

and

$$\Delta B_t = (1+r)^{t-J} \Delta B_J = 0, \ \forall t \geq J+1.$$

That is, after the tax reform, although the level of government debt may vary in the short run, it will stabilize again starting from period J.

Furthermore, from the government budget constraint in period -1 and $J-1$,

$$\begin{aligned}
B_0 &= (1+r)B_{-1} + G - X_{-1}, \\
B_J &= (1+r)B_{J-1} + G - X_{J-1},
\end{aligned}$$

we have

$$B_J - B_0 = (1+r)(B_{J-1} - B_{-1}) - (X_{J-1} - X_{-1}).$$

Because $\Delta B_J = 0$ and $\Delta B_0 = 0$, we have $B_J = B_{J-1}$ and $B_0 = B_{-1}$, the long-run level of government debt is then

$$B_J = B_0 + \frac{X_{J-1} - X_{-1}}{r} = B_0 + \frac{1}{r}\left[\sum_{j=1}^{J}(\hat{x}_j - \bar{x}_j)\right].$$

Note that this is exactly the level of government debt that balances the period government budget constraint at the new stationary equilibrium.

B.4 Life-Cycle Profiles in General Equilibrium

In this section, we present and discuss briefly the life-cycle implications of optimal annual and lifetime income tax reforms in general equilibrium. Figure 11 and Figure 12 display the life-cycle profiles in general equilibrium, corresponding to those in Figure 6 and Figure 7 for the baseline analysis.

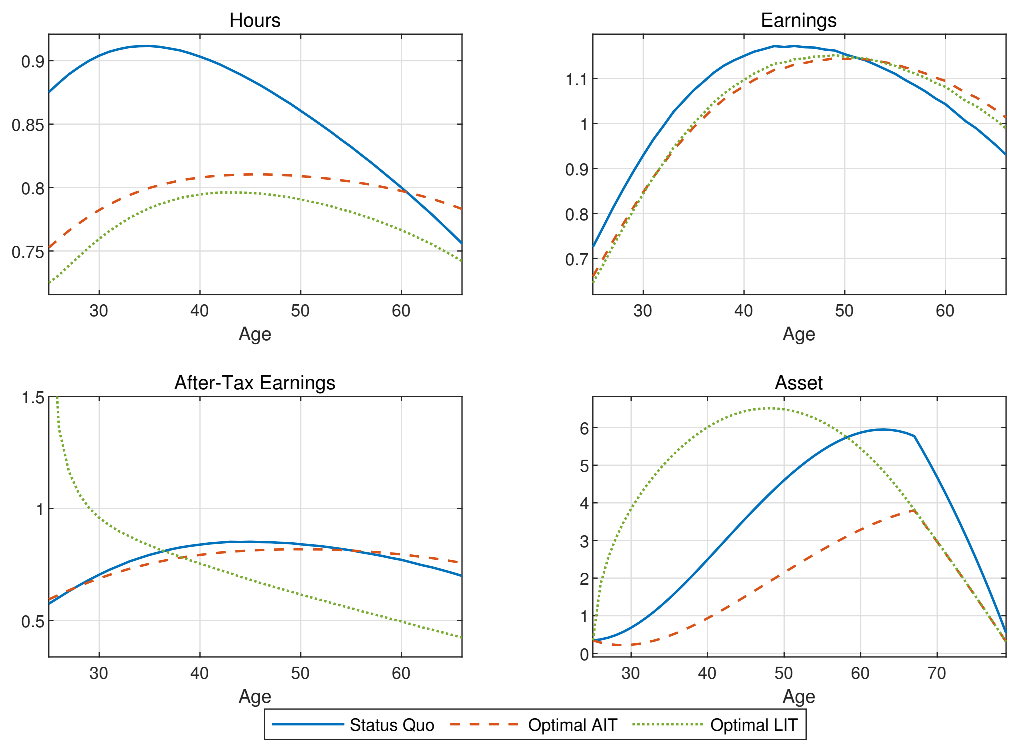

Figure 11: Life-Cycle Profiles of Household Averages
(General Equilibrium)

Notes: This figure plots the life-cycle profiles of cross-sectional means in the status quo economy (blue solid lines), under the optimal annual income tax (red dashed lines), and under the optimal lifetime income tax (green dotted lines).

As the general equilibrium effects lower the interest rate, households prefer to work less early in life, which leads to flatter life-cycle profiles of hours worked. Consequently, household earnings peak later around age 50. Under the optimal annual income tax, the lower early-life earnings and a more progressive tax policy significantly reduce household savings. In contrast, the optimal lifetime income tax redistributes income toward young households, raising their after-tax earnings and leading them to save more in anticipation of higher future taxes. It is worth noting that although total household savings increase under the optimal lifetime income tax and decrease under the optimal annual income tax, the net effect on physical capital remains similar between the two reforms. This is because the changes in government debt required to satisfy the stationary period government budget constraint absorb most of the difference in total household savings.

Labor efficiency improves over the life cycle under both optimal tax policies due to higher equilibrium wages, with greater efficiency gains under the lifetime income tax, consistent with our baseline findings. The life-cycle patterns of hours, earnings, and consumption inequality also largely resemble those in the baseline analysis.

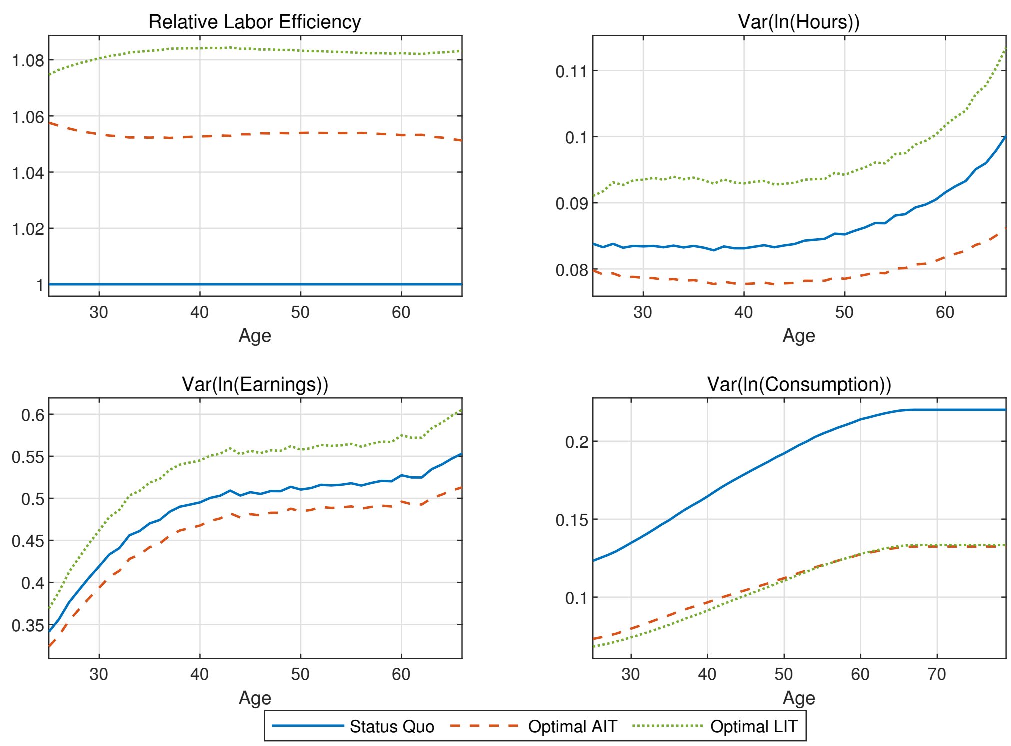

Figure 12: Life-Cycle Profiles of Labor Efficiency and Inequality (General Equilibrium)

Notes: This figure plots the life-cycle profiles of relative labor efficiency and cross-sectional variances in the status quo economy (blue solid lines), under the optimal annual income tax (red dashed lines), and under the optimal lifetime income tax (green dotted lines). Relative labor efficiency is labor efficiency divided by their values in the status quo economy.

B.5 Decomposition of Welfare Gains in General Equilibrium

To further understand the importance of general equilibrium, Table 9 reports step-by-step welfare changes from the status quo economy to the general equilibrium under the optimal annual and lifetime income taxes. Consider first the optimal AIT (column "Annual Tax"). Starting from the status quo, we introduce the wage and interest rate changes reported in Panel B of Table 8 while maintaining the status quo tax policy. These changes capture the direct effects of factor price adjustments. The higher wage induces a welfare gain equivalent to 5.18% of lifetime consumption, whereas the lower interest rate leads to a welfare loss of 3.09%. Together (and accounting for their interaction), these factor price adjustments result in a net welfare gain of 1.88%.

Table 9: Welfare Gains: General vs. Partial Equilibrium Effects

	Annual Tax	Lifetime Tax
General Equilibrium Effects		
Factor Prices	1.88%	1.86%
Wage	5.18%	5.14%
Interest Rate	−3.09%	−3.08%
Interaction	−0.20%	−0.20%
Government Budget	4.48%	4.46%
Partial Equilibrium Effects		
Optimal Policy	1.49%	2.55%
Total Welfare Gain	7.85%	8.87%

Notes: The table reports step-by-step welfare changes from the status quo to the general equilibrium under optimal AIT or LIT.

Following these adjustments, however, the government budget constraint is no longer satisfied. Therefore, in a second step, we adjust the tax level to re-balance the government budget while keeping tax progressivity at the status quo. This captures the indirect effects of factor price adjustments through the government budget constraint. Since the higher wage and lower interest rate imply higher government revenues, the tax level can decline, generating additional welfare gains of 4.48%. Lastly, we implement the optimal AIT while holding the factor prices and tax revenue fixed (as in the partial equilibrium analysis), yielding the remaining welfare gain from tax reform, equivalent to 1.49% of lifetime consumption.

For the optimal LIT (column "Lifetime Tax"), the general equilibrium effects are similar to those under the optimal AIT, suggesting that the direct effects of factor price adjustments and their indirect effect through the government budget constraint are nearly identical. However, in the final step, switching to the optimal LIT yields an additional welfare gain of 2.55% of lifetime consumption, about 1% higher than that from the optimal AIT.

B.6 Within-Period Government Budget Constraint

To focus on the insurance and redistribution role of lifetime income tax, and avoid intergenerational transfers through the income tax system, our baseline analysis imposes a within-cohort government budget constraint when searching for the optimal policy. That is, the total revenue collected by the government from each cohort must remain constant when adjusting the income tax policy. In this section, we instead impose a within-period government budget constraint such that the total revenue collected by the government in each period is constant across alternative polices.

For ease of comparison, Panel A of Table 10 reproduces the baseline results under the within-cohort government budget constraint. Panel B shows that once we switch to the within-period government budget constraint, for both the annual and lifetime income taxes, the optimal policies become more progressive and achieve larger welfare gains. However, the changes are more striking with the lifetime income tax: the optimal tax progressivity increases from 0.267 to 0.540, and the welfare gain grows from 1.60% to 20.64% of lifetime consumption.

Table 10: Cohort vs. Period Government Budget Constraint

	Annual Tax		Lifetime Tax	
	Status Quo	Optimal	Status Quo μ	Optimal
A. Within-Cohort Budget				
Progressivity (μ)	0.137	0.233	0.137	0.267
Level (τ)	0.105	0.113	−0.434	−1.217
Level (comparable)	10.5%	11.3%	14.1%	18.2%
Avg. Tax Rate	13.7%	15.2%	15.9%	20.3%
Welfare Gain	–	0.63%	0.44%	1.60%
B. Within-Period Budget				
Progressivity (μ)	0.137	0.254	0.137	0.540
Level (τ)	0.105	0.113	−0.501	−5.705
Level (comparable)	10.5%	11.3%	10.1%	10.8%
Avg. Tax Rate	13.7%	15.3%	11.9%	12.1%
Welfare Gain	–	0.93%	5.28%	20.64%

Notes: Welfare changes are in consumption equivalent variations as percentages of household lifetime consumption in the status quo. "Level (comparable)" is the average tax rate of a household with constant earnings equal to the status quo average in each working year. "Avg. Tax Rate" is the ratio between total labor income taxes and total labor earnings in the economy.

The exceptionally large welfare gain of the optimal lifetime income tax under the within-period budget constraint likely comes from intergenerational transfers from current to future households through the income tax system, which we verify by computing the transition path from the status quo economy to the optimal stationary equilibrium, similar to the exercises in Section 5.5. Government debt and expenditures are fixed at the status quo levels,[35] and hence the income tax level τ must adjust over time to balance the government period budget constraint along the transition, whereas the tax progressivity μ, and the income tax type if applicable, are changed once-and-for-all at time $t = 0$.

The top-left panel of Figure 13 presents the heterogeneous welfare effects of the annual income tax reform to different generations of households. Recall that generation x enters the economy at time $t = x$, and model age 1 corresponds to data age 25. Only the middle-aged households at the time of tax reform suffer minor welfare losses. Current old and young working households benefit from the tax reform, but less so than future generations. The top-right panel shows that the tax level τ jumps up at the reform and then gradually declines to its level at the optimal stationary equilibrium.

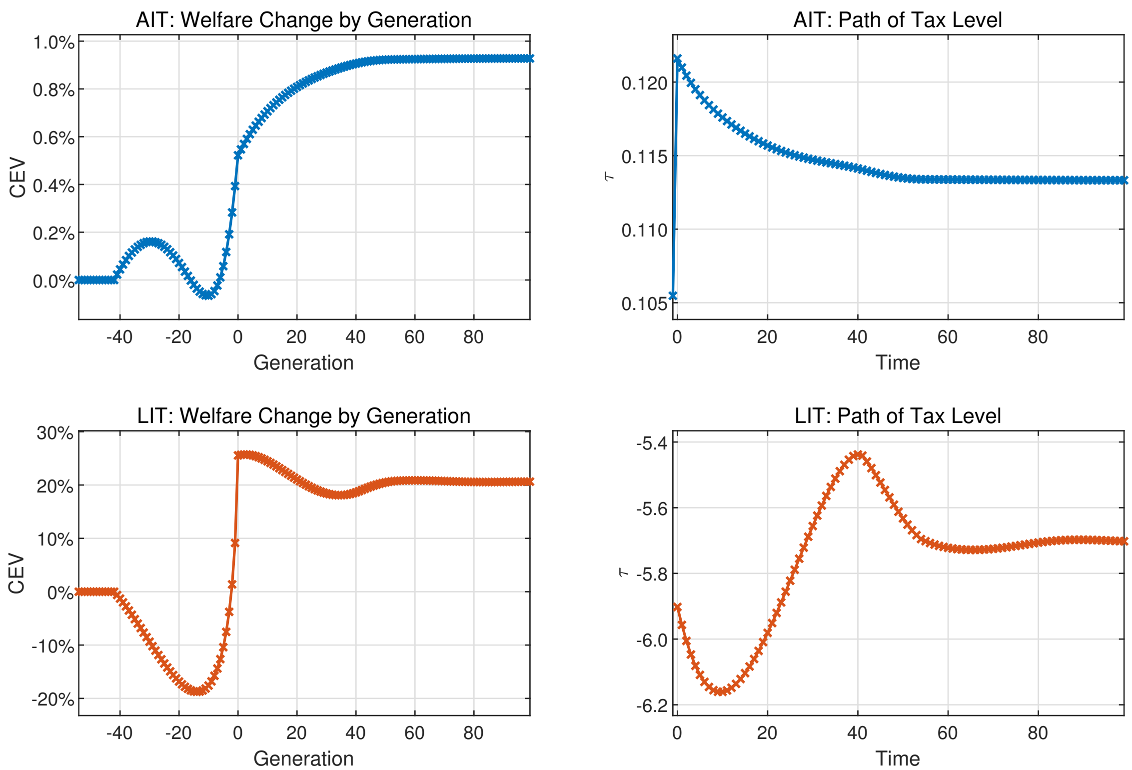

Figure 13: Transition to the Optimal Stationary Equilibrium (Within-Period Government Budget Constraint)

Notes: This figure shows the results related to the transition from the status quo economy to the optimal stationary equilibrium subject to the within-peroid government budget constraint with either annual (top panels) or lifetime (bottom panels) income taxes, under the assumption that the new policy is applied to all households. The left panels display the welfare effects of tax reform on different genearations, and the right panels plot the transition path of income tax level τ that balances the government budget period-by-period. Generation x is born at time x, and tax reform occurs at time 0.

[35] Since the government now collects the same revenue per period in the original and optimal stationary equilibria, the level of government debt no longer needs to change.

The bottom-left panel reveals that most of current working households suffer from the lifetime income tax reform, and the magnitudes of welfare losses are comparable to the large welfare gains enjoyed by future generations. The reason for the massive welfare losses is that most of current households did not receive the subsidies (i.e., negative taxes) to young households under the optimal lifetime income tax, but they still need to pay high taxes to finance such transfers to current and future young households. The bottom-right panel shows that the tax level τ drops to below its long-run optimal level at the commencement of transition; it then grows and overshoots before eventually falling back to the optimal stationary equilibrium level.