A Tale of Two Bases: Progressive Taxation of Capital and Labor Income

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U.S. Congress Joint Committee on Taxation

13 January 2021

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January 13, 2021

Abstract

Macroeconomic models routinely abstract simultaneously from two features of the United States federal tax code: the joint taxation of ordinary capital and labor income, and the special taxation of preferential capital income. In this paper we argue that this abstraction omits a 'portfolio-effect' mechanism where endogenous changes to the ordinary-preferential composition of households' capital income influence individuals' optimal labor and saving decisions through its impact on their effective marginal tax rates. We demonstrate the quantitative importance of this tax detail by simulating provisions from the recently enacted "Tax Cuts and Jobs Act" using a heterogeneous-agent overlapping generations framework.

JEL Codes: C63, E62, H30
Keywords: dynamic scoring; progressive income taxation; modeling tax reform; heterogeneous agents; tax calculator

*A previous version of this paper was circulated under the title "Modeling the Internal Revenue Code in a Heterogeneous-Agent Framework: An Application to TCJA."

†This research embodies work undertaken for the staff of the Joint Committee on Taxation, but as members of both parties and both houses of Congress comprise the Joint Committee on Taxation, this work should not be construed to represent the position of any member of the Committee. This work is integral to the Joint Committee on Taxation staff's work and its ability to model and estimate the macroeconomic effects of tax policy changes.

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1 Introduction

Heterogeneous-agent general equilibrium models have become common tools for tax policy analysis. Despite the rich economic environment in these models, it is routine to specify a progressive tax system for household income that treats all capital and labor income as a single base, or as two distinct bases. This is an abstraction; the United States federal government taxes labor income jointly with *ordinary* capital income as a single base at ordinary rates,[1] while *preferential* capital income is taxed as a separate base at special lower rates.[2] Since in 2017 approximately 58.6% of non-wage income reported by taxpayers was preferential income,[3] the abstraction is not necessarily innocuous. This begs the question: Does the differential in applicable tax rates have implications for household behavior that matter at the aggregate level? Changes to the ordinary-preferential capital income composition of a household's asset portfolio affect the size of their ordinary income tax base, and under a progressive tax schedule, could result in a change to the effective marginal tax rate applied to their ordinary capital and labor income. By altering after-tax returns, this 'portfolio effect' feeds into households' labor and savings decision-making processes.

This paper demonstrates the quantitative importance of accounting for this tax detail using a large-scale overlapping generations (OLG) model with a two-entity production sector for distinct corporate and noncorporate firms. This feature allows for an endogenous composition of household portfolios which can change in response to changes in the pattern of investment across sectors. Crucially, capital income from these portfolios can be decomposed into corporate dividends, noncorporate distributions, interest, and capital gains. So that we can explicitly model the taxation of household capital and labor income as specified in the United States Internal Revenue Code (IRC) and capture the tax detail underlying the portfolio effect, we make use of the internal calculator framework introduced in Moore and Pecoraro (2020b). The internal tax calculator allows for us to compute the portion of this income that is treated as ordinary capital income and combine it with labor income to obtain the ordinary income base, with the residual flow of portfolio income determining the preferential income base. Each base is subsequently taxed according to their respective statutory rate schedules while taking into account other underlying major tax provisions so that households' effective marginal tax rates are endogenous. Descriptions of the model structure and the calibration of tax variables

[1] Ordinary capital income consists of interest income, noncorporate business distributions, short-term capital gains, and nonqualified corporate dividends. In 2017, there were seven tax brackets on the ordinary income statutory tax schedule — 10%, 15%, 25%, 28%, 33%, 35% and 39.6% — where the applicable rates depend on income ranges that vary with filing status.

[2] Preferential capital income consists of long-term capital gains and qualified corporate dividends. In 2017, there were three tax brackets on the preferential capital income statutory tax schedule — 0%, 15%, and 20% — where the applicable rates depend on income ranges that vary with filing status.

[3] This statistic is from data created by the Statistics of Income division of the Internal Revenue Service's 2017 sample of individual income tax returns.

appear in Sections 2 and 3.

Existing approaches to modeling progressive household income taxation in the United States have generally taken one of two forms. The first approach, which ignores the distinction between ordinary and preferential capital income, is to simply add all capital income to labor income and tax both as a single base according to a smooth or piecewise function (Altig and Carlstrom (1999), Ventura (1999), Díaz-Giménez and Pijoan-Mas (2006), Conesa et al. (2009), Kitao (2010), Guner et al. (2011), Nishiyama (2015), Lopez-Daneri (2016), Díaz-Giménez and Pijoan-Mas (2019), Raei (2020a)). The second approach, which acknowledges that the tax treatment of capital and labor income differ, is to maintain independent bases for all capital and labor income by taxing only labor income according to a smooth or piecewise function and taxing capital income at a flat rate(s) (Altig et al. (2001), Conesa et al. (2009), Krueger and Ludwig (2013), Zodrow and Diamond (2013), Krueger and Ludwig (2016), Guvenen et al. (2019), Holter, Krueger, and Stepanchuk (2019), Kindermann and Krueger (2020)). In a similar vein to the latter approach, Gourio and Miao (2011) treat labor and interest income as a single tax base, while using flat tax rates on other capital income types, and DeBacker et al. (2019) use separate tax functions for capital and labor income that condition on the size of the other respective tax base. Despite this large literature, we are not aware of any previous work that allows for the joint taxation of ordinary capital and labor income while simultaneously accounting for the special tax treatment of preferential capital income,[4] leaving the 'portfolio-effect' mechanism we describe in this paper unexplored.

We begin our analysis in Section 4 by illustrating the portfolio-effect mechanism in terms of a partial equilibrium impulse response of households' labor and saving decisions to a one-time capital income recharacterization shock. In Section 5, we then use our complete OLG model to show the quantitative importance of the portfolio effect in general equilibrium. Using the internal tax calculator and the conventional tax specification with independent capital and labor income bases each in turn to determine the tax treatment of household income, we simulate transition paths following the implementation of two different subsets of the recently enacted "Tax Cuts and Jobs Act" (TCJA)[5]: (*i*) the corporate tax rate reduction[6]; and (*ii*) the individual tax provisions[7]. We find that policy-induced changes to the ordinary-preferential composition of households' capital income

[4]This issue has been recognized in prior literature such as Guvenen et al. (2014), who argue that the complexity of capital taxation is a reason to completely abstract from modeling it when studying labor income taxation.

[5]See JCT (2017) for a list of provisions contained in PL 115-97, colloquially known as the "Tax Cuts and Jobs Act".

[6]The previous-law statutory tax rate schedule on corporate income in the US with maximum rate of 35% and replaced it with a single 21% statutory rate beginning in calendar year 2018.

[7]The major changes included an overall reduction in statutory rate tax rates on ordinary income, expansion of the standard deduction, modification of itemized deductions, 20% deduction of qualified business income for pass-through entities, repeal of personal exemptions, and expansion of the child tax credit.

generate quantitatively significant effects on aggregate labor supply and savings behavior from the portfolio effect. On average over the first decade following the corporate rate cut, the increases in aggregate labor supply and the stock of savings are about 6.9 and 1.6 times larger when using the tax calculator because this environment captures the household labor supply and saving incentives that result from a long-run shift towards preferential capital income associated with an expansion of the corporate sector. For the decade following the changes to individual tax provisions, aggregate labor supply and savings increase by an average of about 1.9 and 1.6 times more when using the tax calculator. This results from an immediate and temporary shift towards preferential capital income that occurs due to an increase in equity values, which gives households the incentive to intertemporally shift labor supply forward and increase savings while the relevant effective marginal tax rates are lower.

Our findings imply that while the conventional tax specification may describe income tax liabilities over the income distribution relatively well for the United States (Guner et al., 2014), the simplified specification of household capital income taxation fails to capture the portfolio effect. As this mechanism can generate quantitatively significant behavior that affects the projections of macroeconomic aggregates following a tax reform, accounting for the detailed taxation of labor and capital income should be considered when performing tax policy analysis.

2 Model

In this section we describe the large-scale OLG framework used in this paper: The basic market structure captures the interaction of households, two representative firms, financial intermediaries, and government. Households make savings, consumption, labor, leisure, and residential decisions. Corporate and noncorporate firms hire labor directly from households, and finance their capital investments and productive operations through a combination of debt and equity. Financial intermediaries pool deposits of financial assets from households and allocate their portfolio across business debt and equity, consumer debt, mortgage debt, public debt, and rental housing, passing the return on these investments back to deposit-holding households. Federal, state, and local governments collect taxes from households and firms, using the revenue to make consumption expenditures, public capital investment, and transfer payments. With the exception of mortality risk, all agents have perfect foresight. Population and technological growth in the model economy is assumed to be exogenous so that the model exhibits a balanced growth path in trend-stationary form.

We build upon the household sector developed in Moore and Pecoraro (2020b), which was designed to facilitate the utilization of an internal tax calculator within an OLG model to study the effects of nonconvexities and conditional dependence of tax provisions present in IRC provisions applicable to labor income.[8] We view this as the appropriate platform upon which to introduce the novel two-entity production sector allowing for distinct corporate and noncorporate businesses. Unlike the consolidated business sector used in previous work— where capital income is an implicit composite of interest, capital gains, and business distributions — the two-entity framework allows for distinct flows of income from corporate dividends, noncorporate distributions, interest and capital gains. With the ability to decompose capital income by type, we can then use the internal tax calculator to explicitly account for the special tax treatment of preferential capital income, which most corporate dividends and capital gains receive, while simultaneously capturing the joint tax treatment of labor and ordinary capital income.

In addition to explicitly modeling the statutory tax rate schedules for ordinary and preferential income, the internal tax calculator also incorporates other major provisions in the tax code.[9] This is crucial for our analysis because households' effective marginal tax rates on a given source of income often differ from their statutory marginal tax rates because of the phasing-in and -out of underlying provisions.[10] For example, in 2017 a single household beginning with taxable ordinary income of $251,500 would face a statutory marginal tax rate of 33% until their income exceeds $416,700. However, because their personal exemption(s) would begin to phase out at $251,500 and completely phase-out at $384,000, their effective marginal tax rate on ordinary income would exceed their statutory tax rate between $251,500 and $384,000. Other provisions — such as the earned income credit, child tax credit, certain itemized deductions and the overall limitation on itemized deductions — can similarly generate a wedge between the statutory and effective marginal tax rate on ordinary income. When combined with the proper accounting of ordinary and preferential income, the endogeneity of effective marginal tax rates on household income completes the tax detail necessary to capture the portfolio effect.

Finally, there is substantial heterogeneity and a large choice set present in the household sector of the model described in Section 2.2. This complexity is not extraneous; it is necessary to explicitly model the major IRC provisions in the internal tax calculator that generate the endogenous wedges between statutory and effective marginal tax rates described above. For example, owner-occupied housing is included in our model because taxpayers who itemize deductions will receive a deduction for mortgage interest. To the extent that mortgage size depends on income, this wedge is affected by its inclusion. Most

[8]In particular, expansions to the previous work described in this paper reflect a version of the OLG model built by the authors for use by the Joint Committee on Taxation in providing the United States Congress with macroeconomic analyses of major tax legislation.

[9]These additional provisions include the special treatment of social security income, personal and dependent exemptions, standard deduction, earned income credit, child tax credit, home mortgage interest deduction, state and local income, sales, and property tax deductions, charitable giving deduction, the limitation on overall itemized deductions, net investment income and Medicare surtaxes, and the dependent care credit.

[10]See CBO (2019) for a historical analysis of statutory vs. effective federal tax rates on labor income.

importantly, modeling the underlying tax provisions means that we can remain agnostic about how endogenous changes to households' portfolio composition affect their effective marginal tax rates.

2.1 Firms

Goods production occurs in two perfectly competitive sectors, corporate and noncorporate, which differ in terms of tax treatment and the distribution of profits.[11] Firms within each sector finance capital expenditures using a combination of bonds and equity obtained from perfect financial markets, hire labor from perfect labor markets, and use these inputs to produce output at profit maximizing levels. Output produced within each sector is assumed to be an identical numéraire good. As in Gervais (2002), Fernánez-Villaverde and Krueger (2010), and Cho and Francis (2011), the output good can costlessly be transformed by households into a consumption good, owner-occupied housing services, or a liquid financial asset.

Growth in technological efficiency, A_t, is assumed to be labor-augmenting to be consistent with a balanced growth path. It evolves identically within each sector according to $A_{t+1} = \Upsilon_A A_t$, where $\Upsilon_A = (1 + \upsilon_A)$ is the exogenous annual gross rate of technological growth. Production in both sectors is assumed to use constant returns to scale Cobb-Douglas technology, with the following aggregate production function:

$$Y_t^q = Z^q (G_t)^g (K_t^q)^\alpha (A_t N_t^q)^{1-\alpha-g} \quad \text{for} \quad q = c, n \tag{2.1}$$

where $G_t = G_t^{fed} + G_t^{sl}$ is the sum of beginning-of-period public capital owned by the federal, state and local governments, K_t^q and N_t^q are beginning-of-period productive private capital and effective labor employed in each sector $q = c, n$, and Z^q is a scale parameter. We include public capital as a complement to private inputs in an aggregate production function with constant returns to scale. The implied decreasing returns to scale for private factors of production is critical for our analysis, as it allows for us to obtain an interior solution with our two entity - single output good framework. Moreover, the presence of a public factor input along with our assumption of perfect financial and labor markets leads to economic rents which are fully captured by firms.

An endogenous share $\Lambda_t^c < 1$ of aggregate effective labor, determined by the equalization of cross-sector marginal products of labor under perfect labor markets, is employed in the corporate sector with the residual share $\Lambda_t^n = 1 - \Lambda_t^c$ employed in the noncorporate sector. Corporate and noncorporate labor inputs are then $N_t^c = \Lambda_t^c N_t$ and $N_t^n = (1 - \Lambda_t^c) N_t$ respectively.

[11] We do not model the choice of a given firm to be a corporate or noncorporate entity as in Raei (2020b). Rather, we allow for the relative size of the representative corporate and noncorporate firms to depend on their investment and hiring choices.

We assume a one-period time-to-build for investment in productive private capital, so that the capital used for production in the current period is predetermined by investment decisions from the previous period. Investment decisions that cause deviations from the steady-state rate of capital accumulation generate adjustment costs subject to the convex cost function Ξ_t:

$$K^q_{t+1} = (1 - \delta^K)K^q_t + I^q_t - \Xi^q_t \quad \text{for } q = c, n \tag{2.2}$$

$$\Xi^q_t = \frac{\xi^K}{2}(\frac{I^q_t}{K^q_t} - \Upsilon_P\Upsilon_A + 1 - \delta^K)^2 K^q_t \quad \text{for } q = c, n \tag{2.3}$$

Finally, we assume that the debt portion of total resources used to finance investment in each sector is an exogenous, time-invariant ratio of the private capital stock, $\varkappa^{b,q}$:

$$B^q_t = \varkappa^{b,q} K^q_t \quad \text{for } q = c, n \tag{2.4}$$

where B^q_t is the beginning-of-period net stock of debt held by the representative firm in sector q.

2.1.1 Corporate Sector

The corporate firm finances expenditures with debt (bonds) and equity (stock shares). Profit is remitted back to shareholders through dividends. Gains are realized when the value of corporate shares increase. As in Poterba and Summers (1984) and Hubbard et al. (1995), the after-tax rate of return to the marginal investor-household R^c_t depends on both capital gains gns^c_t and dividend payouts div_t occurring in period t:

$$R^c_t = \frac{(1 - \tau^g_t)gns^c_t + (1 - \tau^d_t)div_t}{V^c_t} \tag{2.5}$$

where τ^g_t is the aggregate accrual-equivalent tax rate on capital gains, τ^d_t is an aggregate tax rate on dividends, and V^c_t is the value of the representative corporate firm. Capital gains are equal to the change in the value of the firm less the value of new share issues, shr_t:

$$gns^c_t = V^c_{t+1} - V^c_t - shr_t \tag{2.6}$$

The firm's objective is to choose the time path of private capital K^c_t and hire the quantity of effective labor input N^c_t that maximize the firm's value at time t. Rearranging equation (2.5) for V^c_t and solving forward gives the firm's objective function below. Letting $\beta^c_t \equiv \frac{1-\tau^g_t}{R^c_t+1-\tau^g_t}$, the corporate firm will maximize:

$$V_t^c(K_t^c) = \max_{N_t^c, K_{t+1}^c} \frac{(1-\tau_t^d)div_t - (1-\tau_t^g)shr_t}{R_t^c + 1 - \tau_t^g} + \beta_t^c V_{t+1}^c(K_{t+1}^c) \tag{2.7}$$

subject to:

1. a cash flow restriction:

$$ern_t^c + B_{t+1}^c - B_t^c + shr_t = div_t + I_t^c + txl_t^c + slt_t^c \tag{2.8}$$

2. the law of motion for capital in equation (2.2),
3. the debt issues rule in equation (2.4), and
4. the dividend payout rule in equation (2.9) defined below.

where the cash flow restriction in equation (2.8) states that the corporate firm's intra-period inflows — earnings ern_t^c, new debt issues $B_{t+1}^c - B_t^c$, and new share issues shr_t — must be equal to outflows — dividend payments div_t, investment in productive capital I_t^c, federal tax liabilities txl_t^c, and state and local tax liabilities slt_t^c.

As in Zodrow and Diamond (2013) the dividend payout ratio $\varkappa^d$ is assumed to be exogenous, which is here expressed relative to earnings ern_t^c less federal tax liability txl_t^c:

$$div_t = \varkappa^d(ern_t^c - txl_t^c) \tag{2.9}$$

Corporate earnings are equal to revenue from production, less wage and net interest expense:

$$ern_t^c = Y_t^c - w_t N_t^c - i_t B_t^c \tag{2.10}$$

where i_t is the real interest rate on private bonds. Corporate tax liabilities at the federal level are equal to the federal corporate aggregate effective marginal tax rate, τ_t^c, times the taxable earnings base (which allows for wage expensing and other deductions), less credits:

$$txl_t^c = \tau_t^c\left(Y_t^c - w_t N_t^c - ded_t^c\right) - crd_t^c \tag{2.11}$$

where ded_t^c and crd_t^c are the corporate firm's non-wage tax deductions are credits respectively.

Lastly, corporate tax liabilities at the state and local level are assumed to be proportional to corporate earnings for simplicity:

$$slt_t^c = \tau_t^{slc} ern_t^c \tag{2.12}$$

2.1.2 Noncorporate Sector

While the noncorporate firm explicitly issues debt in a similar fashion to the corporate firm, shares are not explicitly sold or bought back. Net distributions dst_t incorporate the portion of earnings that are passed through to investors and taxed at the household level. We therefore specify that from the view of the marginal investor-household, the after-tax rate of return to noncorporate firm equity, R_t^n, depends both on capital gains, gns_t^n, and aggregate pass-through distributions net of tax liabilities $dst - txl^n$:

$$R_t^n = \frac{(1-\tau_t^g)gns_t^n + dst_t - txl^n}{V_t^n} \tag{2.13}$$

where capital gains are the change in the value of the noncorporate firm:

$$gns_t^n = V_{t+1}^n - V_t^n \tag{2.14}$$

Similar to the corporate firm, the objective function of the noncorporate firm is derived by solving equation 2.13 forward. Letting $\beta_t^n \equiv \frac{(1-\tau_t^g)}{R_t^n+1-\tau_t^g}$, the objective of the noncorporate firm is to choose labor and private capital inputs to maximize:

$$V_t^n(K_t^n) = \max_{N_t^n, K_{t+1}^n} \left(\frac{dst_t - txl^n}{R_t^n + 1 - \tau_t^g} \right) + \beta_t^n V_{t+1}^n(K_{t+1}^n) \tag{2.15}$$

subject to:

1. the cash flow restriction

$$ern_t^n + B_{t+1}^n - B_t^n = dst_t + I_t^n \tag{2.16}$$

2. the law of motion for capital in equation (2.2), and

3. the debt issues rule in equation (2.4).

As with the corporate firm, earnings are equal to revenue less wages and interest payments on outstanding debt:

$$ern_t^n = Y_t^n - w_t N_t^n - i_t B_t^n \tag{2.17}$$

The aggregate tax liability for noncorporate income txl_t^n is equal to the noncorporate aggregate effective marginal tax rate, τ_t^n, times the taxable earnings base (which allows for wage expensing and other deductions), less credits:

$$txl_t^n = \tau_t^n \left(Y_t^n - w_t N_t^n - ded_t^n\right) - crd_t^n \tag{2.18}$$

Unlike the corporate firm, the noncorporate firm is not liable for taxes at the business-entity level and txl_t^n therefore does not enter the government's budget constraint directly.

Rather, noncorporate distributions are passed through to the household-level where they are taxed jointly with households' other income and remitted by the government. A description of our method for incorporating these tax liabilities at the household level is discussed in Section 2.4.

2.2 Households

The economy is populated with overlapping generations of finitely-lived households who are ex ante heterogeneous with respect to family type, single $f = s$ or married $f = m$, age, $j = 1, \ldots, J$, labor productivity types, $z = 1, \ldots, Z$, and endowment type, $e = 1, \ldots, E$. Survival is certain until retirement age $j = R$ such that $\pi_j = 1$ for $j = 1, \ldots, R$, and thereafter is uncertain, $\pi_j < 1$ for $j = R+1, \ldots, J-1$, until the maximum age J where $\pi_J = 0$. There is no other form of uncertainty. The population is assumed to grow exogenously at the gross rate of Υ_P.

The value function for a household of age j, with permanent labor productivity type z, and family composition f is $V_{t,j}^{f,z}(a_j, h_j^o)$, which is increasing in the two household-level state variables:[12] beginning-of-period financial wealth a_j; and owner-occupied housing stock, h_j^o. Each household chooses optimal future values a_{j+1} and h_{j+1}^o while simultaneously choosing optimal intratemporal choices to maximize instantaneous utility $U_{t,j}^{f,z}$: current market labor supply n_j; ordinary consumption c_j^i; charitable giving c_j^g;[13] and rental housing h_j^r. Ordinary consumption and charitable giving are complimentary, and are combined into non-housing consumption composite good c_j. Owner-occupied housing and rental housing services are perfect substitutes, the choice of which is represented by the housing service composite good hs_j.[14] The two composite goods are themselves nested into a third composite good x_j in a CES fashion.

To avoid problems associated with the curse of dimensionality, which are amplified by usage of the internal tax calculator, we follow Chang et al. (2011) and specify indivisible market labor supply $n_j \in \mathbb{N} \equiv \{0, n^{PT}, n^{FT}\}$ such that individuals may choose between no work, part-time work, or full-time work.[15,16] Costs to market work include a utility cost and a monetary cost. To allow for an operative extensive margin, we follow Holter et al. (2019) and specify that single households face a fixed utility loss of F^s if the individual

[12] While prices, taxes and utility are time dependent, the household keeps track of choice variables over time using age. To reduce notational clutter, we omit the time subscript in what follows.

[13] We assume a 'warm-glow' motive (Andreoni, 1989) to incentivize households to make charitable gifts, which are made in terms of final goods, and are assumed to be received by agents outside of the model.

[14] We interpret housing services as the household's stock of residential capital and durable goods.

[15] Using the internal tax calculator requires evaluating the tax consequences of every possible combination of choice variables at every possible household-level state. The number of combinations is significantly reduced by using discrete labor supply choice set instead of a continuous one.

[16] As emphasized in Chang et al. (2013), indivisible labor implies that the aggregate labor supply elasticity is endogenous and depends on the distribution of reservation wages across households, which itself does not fully depend on the parameterization of the labor sub-utility function.

enters the labor force, while married households face a fixed utility loss of F^m if the secondary earner works. In addition, we follow Guner et al. (2011) and specify that (i) the monetary child-care cost, $\kappa_j^{f,z}$, that is a function the number of qualifying dependents within that household, $\nu_j^{f,z}$, and the market work hours of the single and secondary worker; and (ii) the disutility of market labor function for single and secondary worker contains a separable term $\varphi\nu_j^{f,z}$ which captures the interaction between lifecycle disutility of work and the presence of children.

We incorporate a simple structure of home production, where the time each individual spends on home production exogenously varies inversely with their chosen quantity of market labor through the function $nh_j^f(n_j)$, with the quantity of home-produced consumption obtained through the function $ch_j(nh_j^f)$. Defining ordinary consumption as the sum of market and home-produced consumption goods, our specification of time use implies that households face a loss in ordinary consumption which varies positively with market labor hours. The presence of this cost in our model induces heterogeneity in market labor hours at older ages as documented by Kuhn and Lozano (2008).

The objective of this household's optimization problem for a known policy regime is:[17]

$$V_{t,j}^{f,z}(a_j, h_j^o) = \begin{cases} \max\limits_{\substack{a_{j+1}, h_{j+1}^o, \\ x_j, n_j \in \mathbb{N}}} U_{t,j}^{s,z}(x_j, n_j) + \beta\pi_j V_{t+1,j+1}^{s,z}(a_{j+1}, h_{j+1}^o) & \text{if} f = s \\ \\ \max\limits_{\substack{a_{j+1}, h_{j+1}^o, \\ x_j, n_j^1, n_j^2 \in \mathbb{N}}} U_{t,j}^{m,z}(x_j, n_j^1, n_j^2) + \beta\pi_j V_{t+1,j+1}^{m,z}(a_{j+1}, h_{j+1}^o) & \text{if} f = m \end{cases} \tag{2.19}$$

$$U_{t,j}^{f,z}(x_j, n_j) \equiv \begin{cases} \max\limits_{h_j^r, c_j^i, c_j^g} \log(x_j) - \psi^s \frac{(n_j + \varphi\nu_j^{s,z})^{1+\zeta^s}}{1+\zeta^s} - F^s(n_j) & \text{if } f = s \\ \\ \max\limits_{h_j^r, c_j^i, c_j^g} \log(x_j) - \psi^{m,1} \frac{(n_j^1)^{1+\zeta^{m,1}}}{1+\zeta^{m,1}} - \psi^{m,2} \frac{(n_j^2 + \varphi\nu_j^{m,z})^{1+\zeta^{m,2}}}{1+\zeta^{m,2}} - F^m(n_j^2) & \text{if } f = m \end{cases} \tag{2.20}$$

where:

$$y_j \equiv h_j^o + a_j \tag{2.21}$$

$$x_j \equiv \left(\sigma c_j^\eta + (1-\sigma) hs_j^\eta\right)^{1/\eta} \tag{2.22}$$

$$c_j \equiv (c_j^i)^{\theta^{s,z}} (c_j^g)^{(1-\theta^{s,z})} \tag{2.23}$$

[17] The functional form for instantaneous utility is chosen because it is consistent with a balanced growth path in the presence of fixed costs from working. See Holter, Krueger, and Stepanchuk (2019) for a proof.

$$hs_j \equiv \max\{h^o_j, h^r_j\} \tag{2.24}$$

$$c^i_j \equiv \begin{cases} c^M_j + ch^s_j(nh^s_j) & \text{if} f = s \\ c^M_j + ch^{m,1}_j(nh^{m,1}_j) + ch^{m,2}_j(nh^{m,2}_j) & \text{if} f = m \end{cases} \tag{2.25}$$

Households choices are restricted by the following budget constraint:

$$c^M_j + c^g_j + p^r_t h^r_j + a_{j+1} + h^o_{j+1} \leq (1 + r^p_t)a_j + (1 - \delta^o)h^o_j + i^{f,z}_{t,j} - \mathcal{T}^{f,z}_{t,j} - \kappa^{f,z}_j - \xi^H_j \tag{2.26}$$

where expenditures on the left-hand side are market consumption c^M_j, charitable giving c^g_j, rental housing $p^r_t h^r_j$, end-of-period stock of financial wealth a_{j+1}, and end-of-period owner-occupied housing h^o_{j+1}. Available resources on the right-hand side are the sum of the gross return to beginning-of-period financial wealth $(1 + r^p_t)a_j$ deposited at a financial intermediary, beginning-of-period owner-occupied housing stock less economic depreciation $(1 - \delta^o)h^o_j$, and non-capital income income $i^{f,z}_{t,j}$ less net tax liabilities $\mathcal{T}^{f,z}_{t,j}$, child-care costs $\kappa^{f,z}_j$, and housing transaction costs ξ^H_j.

Non-capital income is equal to labor income during working years and equal to social security payments $ss^{f,z}_j$ during retirement:

$$i^{f,z}_{t,j} \equiv \begin{cases} n_j w_t \mathrm{z}^{s,z}_j + ss^{s,z}_j & \text{if} f = s \\ (n^1_j + \mu^z n^2_j) w_t \mathrm{z}^{m,z}_j + ss^{m,z}_j & \text{if} f = m \end{cases} \tag{2.27}$$

where w_t is the market real wage rate, $\mathrm{z}^{f,z}_j$ is demographic-specific labor productivity, and $0 < \mu^z \leq 1$ is an exogenous productivity wedge between the primary and secondary workers for married households. Child-care costs take the form:

$$\kappa^{f,z}_j \equiv \begin{cases} cc^{s,z} \nu^{s,z}_j n_j & \text{if} f = s \\ cc^{m,z} \nu^{m,z}_j n^2_j & \text{if} f = m \end{cases} \tag{2.28}$$

where $cc^{f,z} > 0$ is an exogenous scale parameter for cost per child. The housing transaction costs is non-zero when a household changes their residential status, taking the form of $\phi \geq 0$ share end-of-period housing services:

$$\xi^H_j = \begin{cases} \phi h^o_{j+1} & \text{if } h^o_j = 0 \\ \phi h^r_{j+1} & \text{if } h^o_j > 0 \end{cases} \tag{2.29}$$

Following Gervais (2002) and Cho and Francis (2011), households are permitted to borrow and accumulate debt in excess of savings subject to the following restrictions:

$$y_j \geq \begin{cases} \underline{y}^{s,z} & \text{if } h_j^o = 0 \\ \gamma h_j^o & \text{if } h_j^o > 0 \end{cases} \tag{2.30}$$

where $\underline{y}^{s,z} < 0$ is the lower-bound of the real wealth support for renters and the parameter $0 \leq \gamma \leq 1$ can be interpreted as the down-payment ratio, or the minimum equity which a homeowner may hold in their home. Both rental housing and owner-occupied housing are subject to minimum sizes, where $\underline{h}^r < \underline{h}^o$ making rentals relatively more affordable.

$$hs_j \geq \underline{h}^r \tag{2.31}$$

$$h_j^o \geq \underline{h}^o \quad \text{if} \quad h_j^o > 0 \tag{2.32}$$

Further we assume that ordinary consumption must be at least as large as a subsistence level, $\underline{c}^i$, and that households consuming at this level do not make charitable gifts:

$$c_j^i \geq \underline{c}^i \tag{2.33}$$

$$c_j = c_j^i \quad \text{if} \quad c_j^i = \underline{c}^i \tag{2.34}$$

Should the household be unable to afford both $\underline{c}^i$ and $\underline{h}^r$, the federal government will provide a conditional welfare transfer of the following value:

$$trw_j^{f,z} = \max\left\{0, \underline{c}^i + p^r \underline{h}^r - bdgt_j^{f,z}\right\} \tag{2.35}$$

where $bdgt_j^{f,z}$ denotes the right-hand side of the household budget constraint in Equation (2.26).

It is assumed that households enter the economy with initial financial wealth of an exogenous a_1 and zero owner-occupied housing. Should a household live to the maximum age J, they are assumed to die with zero net worth:

$$y_1 = a_1 \tag{2.36}$$

$$h_1^o = y_{J+1} = 0 \tag{2.37}$$

$$V_{t,J+1}^{s,z} = 0 \tag{2.38}$$

Should a household instead die before reaching the maximum age J, they are assumed to incur end-of-life expenditures, c_t^{eol}, with their estates costlessly liquidated and collected by the government, taxed, and redistributed in an exogenous fashion to agents aged $j = 1$.[18] Given an exogenous linear tax rate on estates of τ_t^{beq} and an exogenous distribution of bequests which aggregates to $\bar{\Lambda}$, end-of-life expenditures are computed as a residual so

[18]See Appendix A.1.1 for details.

that:

$$c_t^{eol} = (1 - \tau_t^{beq}) \int_{\mathbb{Z}} \int_{\mathbb{J}} (1 - \pi_j) \sum_{f=s,m} y_{t+1,j+1} \Omega_{t,j}^{f,z} \; dj \; dz \; - \bar{\Lambda} \tag{2.39}$$

2.3 Financial Intermediaries

The financial sector is perfectly competitive, consisting of overlapping cohorts of identical, two-period lived financial intermediaries with the technology to pool savings from households and invest in financial assets and rental property. Each period the representative intermediary of a given cohort will make the portfolio decision on behalf of households by collecting end-of-period deposits D_{t+1} and deciding upon an investment allocation. These deposits may be allocated across corporate and noncorporate equity V_{t+1}^c and V_{t+1}^n, corporate and noncorporate bonds B_{t+1}^c and B_{t+1}^n, federal government bonds B_{t+1}^g, and rental housing property H_{t+1}^r so that:

$$D_{t+1} = V_{t+1}^c + V_{t+1}^n + B_{t+1}^g + B_{t+1}^c + B_{t+1}^n + H_{t+1}^r \quad \forall t \tag{2.40}$$

The assets remaining at the end-of-life for each cohort are costlessly transferred to the subsequent cohort.

Corporate and noncorporate equity yield dividends or distributions, and capital gains. While corporate and noncorporate bonds yield a pretax rate of return of i_{t+1}, we assume that investment in government bonds yields a low, "safe" pretax rate of return ρ_{t+1}, which depends positively on both the private bond rate and the public debt-output ratio:

$$\rho_{t+1} = \varpi i_{t+1} + \varsigma \exp\left(\frac{B_{t+1}^g}{Y_{t+1}}\right) \quad \forall t \tag{2.41}$$

The intermediary rents out housing services at a price of p_{t+1}^r and incurs expenses from the economic depreciation at rate δ^r. For convenience, we denote a given representative intermediary's income as:

$$Inc_{t+1} \equiv div_{t+1} + dst_{t+1} + gns_{t+1}^c + gns_{t+1}^n + (p_{t+1}^r - \delta^r) H_{t+1}^r + \rho_{t+1} B_{t+1}^g + i_{t+1}(B_{t+1}^c + B_{t+1}^c) \quad \forall t \tag{2.42}$$

which is remitted back to households in the form of a portfolio return r_{t+1}^p on their deposits.

Formally, the maximization problem for a given cohort's representative financial intermediary is as follows:

$$\max_{\substack{V_{t+1}^c, V_{t+1}^n, \\ B_{t+1}^c, B_{t+1}^n, H_{t+1}^r}} \quad Inc_{t+1} - r_{t+1}^p D_{t+1} \tag{2.43}$$

where it is assumed that the financial intermediary has perfectly elastic demand for government bonds. A characteristic of the optimal allocation is that no arbitrage opportunities exist in equilibrium. This no-arbitrage condition implies that the after-tax marginal rate of return from across all investment vehicles will be equalized. Recalling the expressions for the after-tax rates of return of corporate and noncorporate equity in equations (2.5) and (2.13), we can express this condition as:

$$R^c_{t+1} = R^n_{t+1} = (1 - \tau^i_{t+1}) i_{t+1} = p^r_{t+1} - \delta^r \quad \forall t \tag{2.44}$$

where τ^i_{t+1} is the aggregate effective marginal tax rate on interest income. Because this expression reflects the aggregate effective marginal after-tax rates of return on each asset in the financial market, this portfolio allocation is optimal on average.

Finally, perfect competition in the financial market implies a zero-profit condition each period for a given cohort's representative intermediary. Households therefore receive a pretax portfolio return on their deposits equal to:

$$r^p_{t+1} = \frac{Inc_{t+1}}{D_{t+1}} \quad \forall t \tag{2.45}$$

which is equivalently the borrowing rate for households with negative financial wealth.

2.4 Government

2.4.1 Household Income Taxation

In this section we detail the tax treatment of household income, which involves the specification of federal labor income taxes, capital income taxes, payroll taxes, state and local taxes, and the special tax treatment of social security benefits. We describe the general framework of household income taxation under our internal tax calculator (ITC) and the conventional tax specification (CTS), each in turn.

We introduce the 'hat-notation' to denote income variables that have been adjusted for inclusion in adjusted gross income (AGI).[19] Adjusted gross labor income, $\hat{i}^{f,z}_{t,j}$, is wage income for working-age households or social security income for retired households. Adjusted gross capital income is $r^p_t \hat{a}^{f,z}_{t,j}$, the deposits of household financial assets held by the financial intermediary, which earn a portfolio return r^p_t, consists of the different capital income flows. Adjusted gross capital income can be decomposed into ordinary and preferential components, $r^p_t \hat{a}^{\boldsymbol{o},f,z}_{t,j}$ and $r^p_t \hat{a}^{\boldsymbol{p},f,z}_{t,j}$ respectively.[20] We define total adjusted gross ordinary income and total adjusted preferential capital income as:

[19]Adjusted gross income is a concept used by the Internal Revenue Service to measure income for tax purposes. This differs from economic income, such as the personal income measures produced by the Bureau of Economic Analysis. See Ledbetter (2007) for a discussion.

[20]In Appendix A.2 we describe our process for capital income aggregation by source, and the process by which adjustments are made to gross economic income to arrive at AGI.

$$ord_{t,j}^{f,z} \equiv \hat{i}_{t,j}^{;z} + r_t^p \hat{a}_{t,j}^{\boldsymbol{o},f,z} \tag{2.46}$$

$$pci_{t,j}^{f,z} \equiv r_t^p \hat{a}_{t,j}^{\boldsymbol{p},f,z} \tag{2.47}$$

where the sum of both makes up total AGI.

Internal Tax Calculator Under the ITC, a given household's net tax income liability $\mathcal{T}_{t,j}^{f,z}$ is equal to tax liabilities on ordinary income, $oit_{t,j}^{f,z}$, plus tax liability on preferential capital income, $cit_{t,j}^{f,z}$, plus tax liabilities associated with the Social Security system for retirees, $\tau_{t,j}^{pr}\hat{i}_{t,j}^{f,z}$, less federal transfer payments, $trs_{t,j}^{f,z}$, plus state and local tax liabilities, $slt_{t,j}^{f,z}$:

$$\mathcal{T}_{t,j}^{f,z} = oit_{t,j}^{f,z} + cit_{t,j}^{f,z} + \tau_{t,j}^{pr}\hat{i}_{t,j}^{f,z} - trs_{t,j}^{f,z} + slt_{t,j}^{f,z} \tag{2.48}$$

Household tax liability on ordinary income, $oit_{t,j}^{f,z}$, is determined by application of a statutory marginal tax rate schedule, deductions, and credits. This mapping from choice variables, state variables and demographic characteristics to a tax liability is developed to be as close to the actual IRC as possible for the provisions modeled: The average tax rate on ordinary income before tax credits, τ_t^o, is determined by the statutory tax rate schedule in the tax calculator, ordinary income $ord_{t,j}^{f,z}$, and deductions $ded_{t,j}^{f,z}$. The structure of deductions varies as some are a function of labor income only, some are a function of broader income sources, and some are a function of tax-preferred consumption choices made by the household (owner-occupied housing, $h_{t,j}^o$ and charitable giving, $c_{t,j}^g$, in our case). All variables affecting possible deductions are listed in Equation (2.51). Due to the refundability of some credits, $crd_{t,j}^{f,z}$ is a function of each income type, deductions themselves, and child care costs, $\kappa_{t,j}^{f,z}$. Formally, ordinary income tax liability is given by:

$$oit_{t,j}^{f,z} = \max\left\{\tau_t^o ord_{t,j}^{f,z}, 0\right\} - crd_{t,j}^{f,z} - tra_t^{f,z} \tag{2.49}$$

$$\tau_t^o = \boldsymbol{\tau}(ord_{t,j}^{f,z} - ded_{t,j}^{f,z}) \tag{2.50}$$

$$ded_{t,j}^{f,z} = \boldsymbol{d}(\hat{i}_{t,j}^{f,z}, ord_{t,j}^{f,z}, pci_{t,j}^{f,z}, h_{t,j}^o, c_{t,j}^g) \tag{2.51}$$

$$crd_{t,j}^{f,z} = \boldsymbol{c}(\hat{i}_{t,j}^{f,z}, ord_{t,j}^{f,z}, ded_{t,j}^{f,z}, pci_{t,j}^{f,z}, \kappa_{t,j}^{f,z}) \tag{2.52}$$

where bold emphasis denotes a generalized function. The last term in equation (2.49), is a productivity type - family composition specific transfer payment $tra_t^{f,z}$, which is used as a non-distortionary method of ensuring that households within a given (f, z) demographic group on average face a target average tax rate on labor income. This transfer may be positive or negative for different household groups, and is zero when the household supplies no labor.

A households' tax liability on preferential capital income depends on their total AGI and a statutory tax rate schedule. We define this relationship with the following function:

$$cit_{t,j}^{f,z} = \boldsymbol{q}(ord_{t,j}^{f,z}, pci_{t,j}^{f,z}) \tag{2.53}$$

This mapping, like that for ordinary income tax liabilities, is developed to be as close to the actual IRC as possible. Preferential capital income sources are taxed at relatively lower rates according to a progressive statutory tax rate schedule.

Working households pay into the Social Security program at proportional payroll tax rate on labor income each period, which applies to all taxable labor income up to a specified threshold. Formally:

$$\tau_{t,j}^{pr} = \boldsymbol{p}\left(\hat{i}_{t,j}^{f,z}\right) \text{ if } \quad j \leq R \tag{2.54}$$

The payroll tax functions are independent of demographic characteristics other than age.

Conventional Tax Specification Under the CTS, a given households' tax liabilities, $\mathcal{T}_{t,j}^{f,z}$, is equal to tax liabilities on wage income, $wit_{t,j}^{f,z}$, plus tax liability on capital income, $\bar{\tau}_{t,j}^{\boldsymbol{k},f} \hat{a}_{t,j}^{f,z} r_t^p$, plus tax liabilities associated with the Social Security system for retirees, $\tau_{t,j}^{pr} \hat{i}_{t,j}^{f,z}$, less federal transfer payments, $trs_{t,j}^{f,z}$, plus state and local tax liabilities, $slt_{t,j}^{f,z}$:

$$\mathcal{T}_{t,j}^{f,z} = wit_{t,j}^{f,z} + \bar{\tau}_{t,j}^{\boldsymbol{k},f} \hat{a}_{t,j}^{f,z} r_t^p + \tau_{t,j}^{pr} \hat{i}_{t,j}^{f,z} - trs_{t,j}^{f,z} + slt_{t,j}^{f,z} \tag{2.55}$$

where labor and capital income are modeled as separate bases to account for their differential tax treatment without interaction.

For the taxation of labor income for working-age households we specify the Bénabou (2002) tax function, a commonly-used tax function for wage income that generates smooth average tax rates and effective marginal tax rates over income (Guner et al., 2014; Heathcote et al., 2017; Holter et al., 2019). This function is continuously differentiable, allows for negative average tax rates to capture the effect of refundable tax credits, and is easily parameterized with the exogenous specification of an effective marginal tax rate and average tax rate at the desired level of aggregation. It takes the following form over adjusted gross labor income:

$$wit_{t,j}^{f,z} = \hat{i}_{t,j}^{f,z} - \lambda_1^f (\hat{i}_{t,j}^{f,z})^{1-\lambda_2^f} - tra_t^{f,z} \quad \text{if} \quad j \leq R \tag{2.56}$$

where λ_1^f and λ_2^f are parameters which together determine the income-weighted average tax rate and effective marginal tax rate applied to adjusted gross labor income at the family composition level of aggregation. As with the ITC, the transfers $tra_t^{f,z}$ are used as a non-distortionary method of targeting changes to the average tax rate on labor income for (f, z) demographic group following a policy change, but set to zero in the initial steady state under the CTS.

Average tax rates on adjusted gross capital income are determined by age group - family composition specific flat tax rates, one each for working single, working married, retired single, and retired married households. These tax rates are denoted by $\bar{\tau}_{t,j}^{\boldsymbol{k},f}$.

While payroll taxes are levied in the same manner as specified under the ITC, the special tax treatment of the Security Security income received by retired households is captured using (f, z) demographic-specific exogenous average tax rate applied to that income, $\bar{\tau}_t^{\boldsymbol{SS},f,z}$:

$$\tau_{t,j}^{pr} = \begin{cases} \boldsymbol{p}\left(\hat{i}_{t,j}^{f,z}\right) & \text{if} \quad j \leq R \\ \bar{\tau}_t^{\boldsymbol{SS},f,z} & \text{if} \quad j > R \end{cases} \tag{2.57}$$

2.4.2 Federal Government

Total taxes collected by the federal government, $T_t^{fed} \equiv txl_t^{hh} + txl_t^c + txl_t^{beq}$, are the sum of tax receipts collected from households, corporations, and on estates left by the dead. These receipts, along with bond issues, are used to finance non-valued public consumption, C_t^{fed}, capital expenditures, I_t^{fed}, and transfer payments to households TR_t^{fed}. The recursive budget constraint of the federal government is written as:

$$I_t^{fed} + C_t^{fed} + TR_t^{fed} \leq T_t^{fed} + B_{t+1}^g - (1 + \rho_t)B_t^g \tag{2.58}$$

where the law of motion for federal public capital follows:

$$G_{t+1}^{fed} = (1 - \delta^g)G_t^{fed} + I_t^{fed} \tag{2.59}$$

Equation (2.58) states that federal public expenditures on non-valued consumption and capital can be no larger than total tax revenue net of transfer payments plus new debt issues, $B_{t+1}^g - B_t^g$, less interest paid on old debt $\rho_t B_t^g$. To rule out explosive debt paths, we maintain the no-Ponzi condition:

$$\lim_{k \to \infty} \frac{B_{t+k}^g}{\prod_{s=0}^{k-1}(1 + \rho_{t+s})} = 0 \tag{2.60}$$

which implies that the current stock of debt is equal to the present-discounted value of all future primary surpluses along any equilibrium path.

Total income taxes collected by the federal government from households, txl_t^{hh} consist of tax liabilities from both labor and capital income, as well as payroll taxes and tax liabilities on social security income. Re-arranging either Equation (2.48) or (2.55), this is obtained as follows:

$$txl_t^{hh} = \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \left(\mathcal{T}_{t,j}^{f,z} + trs_{t,j}^{f,z} - slt_{t,j}^{f,z} \right) \Omega_{t,j}^{f,z} \; dj \; dz \tag{2.61}$$

Total income taxes collected by the federal government from corporations, txl_t^c, are defined in equation (2.11) and repeated here for convenience:

$$txl_t^c = \tau_t^c \left(Y_t^c - w_t N_t^c - ded_t^c \right) - crd_t^c$$

Taxes are collected on estates left by deceased households. We specify that the tax rate τ_t^{beq} is linear and unrelated to either the benefactor or beneficiary household's other income. Letting $y_{t+1,j+1}$ denote the sum of a given household's end-of-period financial wealth $a_{t+1,j+1}$ and owner-occupied housing wealth $h_{t+1,j+1}^o$, taxes collected on accidental bequests can be expressed as:

$$txl_t^{beq} = \tau_t^{beq} \int_{\mathbb{Z}} \int_{\mathbb{J}} (1 - \pi_j) \sum_{f=s,m} y_{t+1,j+1} \Omega_{t,j}^{f,z} \; dj \; dz \tag{2.62}$$

In addition to social security payments to retirees, $ss_{t,j}^{f,z}$, households receive transfer payments from the federal government, $trs_{t,j}^{f,z} \equiv trl_t + trw_{t,j}^{f,z}$, which is the sum of lump-sum net transfers and conditional welfare transfers respectively. Aggregate federal government transfers therefore can be expressed as:

$$TR_t^{fed} = \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \left(ss_{t,j}^{f,z} + trs_{t,j}^{f,z} \right) \Omega_{t,j}^{f,z} \; dj \; dz \tag{2.63}$$

2.4.3 State and Local Government

Total taxes collected by the composite state and local government T_t^{sl} are the sum of tax receipts collected from households and corporations. These receipts are assumed to be spent on non-valued state and local composite government consumption expenditures C_t^{sl} and investment in productive public capital I_t^{sl}. We specify an intraperiod balanced-budget constraint such that:

$$I_t^{sl} + C_t^{sl} = T_t^{sl} \tag{2.64}$$

where the law of motion for state and local public capital follows:

$$G_{t+1}^{sl} = (1 - \delta^g) G_t^{sl} + I_t^{sl} \tag{2.65}$$

Tax liabilities owed by households at the state and local level are assumed to be proportional to taxable labor income and owner-occupied housing:

$$slt_{t,j}^{f,z} \equiv \tau_t^{sl}\hat{i}_{t,j}^{f,z} + \tau_t^{slp}h_{t,j}^{o} \tag{2.66}$$

where τ_t^{sl} is a linear tax rate taken to represent potentially deductible state and local income and sales tax and τ_t^{slp} is a linear average tax rate on owner-occupied property. Tax liabilities owed by corporations at the state and local level were specified in equation (2.12) but repeated here for convenience:

$$slt_t^c = \tau_t^{slc} ern_t^c$$

Aggregate state and local taxes can therefore be expressed as:

$$T_t^{sl} = \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} slt_{t,j}^{f,z} \Omega_{t,j}^{f,z} \; dj \; dz + slt_t^c \tag{2.67}$$

2.5 Equilibrium

Equilibrium is formally defined in Appendix B in terms of a trend-stationary transformation of the model. Here, we informally define an equilibrium as a collection of household decision rules that maximize households' utility subject to household budget constraints; a collection of economic aggregates that are consistent with household behavior and the associated measure of households; profit-maximizing behavior by the corporate and non-corporate firms; a set of prices that facilitate cross-sector price-equalization and clearing in factor, asset, and goods markets; and an associated set of policy aggregates that are consistent with budget constraints of the federal, state and local governments. When in trend-stationary form, our model exhibits an equilibrium balanced growth path.

3 Calibration

The set of parameters to be calibrated include both non-tax and tax policy parameters, both of which rely heavily on use of the Joint Committee on Taxation's Individual Tax Model (JCT-ITM) for specification, which makes use of data from individual tax returns filed with the Internal Revenue Service and compiled by the Statistics of Income (SOI) division.[21] In calibrating the model, we vary the use of long-run historical data, recent observations, and projections to construct parameter values in targeting the 2017 United States economic environment and tax law as closely as possible for the initial steady-state baseline equilibrium.

[21] Joint Committee on Taxation's Individual Tax Model is in principle similar to NBER's TAXSIM model. However, while TAXSIM makes use of the SOI division public use files, the JCT-ITM generally uses more a recent, confidential sample of tax returns from the SOI division that contains a broader set of variables than do the public use data. For more information, see JCT (2015).

3.1 Non-Tax Policy Parameters and Targets

The calibration strategy for household demographics, characteristics, and preferences generally follows that described in Moore and Pecoraro (2020b), with deviations from that strategy described in Appendix A.1.1. The calibration strategy for the production sector and non-tax portion of government in our economy is described Appendices A.1.2 and A.1.3. Select exogenous parameters used are summarized in Table A1, with key aggregate targets for labor supply, housing and business capital accumulation, and capital income are summarized in Tables A2 and A3.

3.2 Tax Policy Parameters and Targets

3.2.1 Adjustments to Gross Income

Adjusted gross income is a concept used by the Internal Revenue Service to measure income for tax purposes, which differs from the measures of economic income produced by the Bureau of Economic Analysis (Ledbetter, 2007). Since gross income variables within the model are calibrated in terms of economic income, adjustments to gross income must be made when using either the internal tax calculator or the conventional tax system to arrive at the appropriate base. This adjustment process, which makes use of 'calibration ratios', is described in Appendix A.2.

3.2.2 Capital Income Decomposition

The share of each gross capital income type k to be treated as ordinary, $s^{\boldsymbol{o}}_{t,k}$, or preferential, $s^{\boldsymbol{p}}_{t,k}$, are computed as the product of two terms. Let $\mu_{t,k}$ denote the endogenous share of total portfolio income for a given capital income type k, so that $\sum \mu_k = 1$. Next, let $\bar{\mu}^o_{t,k}$ denote the exogenous share of a given capital income type k that is treated as ordinary for tax purposes, which is estimated by the JCT-ITM for 2017.[22] The portfolio shares for each k can then be obtained as follows:

$$
\begin{aligned}
s^{\boldsymbol{o}}_{t,k} &= \bar{\mu}^o_{t,k}\mu_{t,k} \\
s^{\boldsymbol{p}}_{t,k} &= (1-\bar{\mu}^o_{t,k})\mu_{t,k}
\end{aligned}
$$

where by construction the aggregate consistency condition $\Sigma_k \left(s^{\boldsymbol{o}}_{t,k} + s^{\boldsymbol{p}}_{t,k}\right) = 1$ holds. These shares are free to vary with policy through endogenous changes to μ_k. Multiplying a households' financial income by either $s^{\boldsymbol{o}}_{t,k}$ or $s^{\boldsymbol{p}}_{t,k}$ yields the ordinary or preferred quantity

[22] The assumed portions of noncorporate business income, dividend income, capital gains, interest income, and rental income treated as ordinary are 100%, 25.3%, 9.5%, 60%, and 100% respectively.

of capital income of type k. Table 3 shows the decomposition of aggregate household capital income that results from this process for the initial steady state equilibrium.

3.2.3 Household Taxation with the Internal Tax Calculator

The internal tax calculator explicitly models the following individual tax provisions in the Internal Revenue Code for 2017: *the statutory tax rate schedule for ordinary income, statutory tax rate schedule for preferential income, special treatment of social security income, personal and dependent exemptions, standard deduction, earned income credit, child tax credit, home mortgage interest deduction, state and local income, sales, and property tax deductions, charitable giving deduction, net investment income and Medicare surtaxes, and the dependent care credit.*

To ensure that the average federal tax rates on adjusted gross labor income for the average household in each (f, z) demographic in the model match those computed by the JCT-ITM, we set $tra^{f,z}$ endogenously in the initial steady state as described in Moore and Pecoraro (2020b). The fit of these average tax rates to the targets is shown in Tables 1 and 2, which display average adjusted gross labor income and average labor income tax liability, both for each (f, z) demographic.[23]

The OASDI portion of the payroll tax rate of 12.4% is applied to adjusted gross labor income up to the 2017 tax-law threshold of $127,200 for each individual worker. In particular, we allow for different OASDI bases for each potential worker in married households. So that payroll tax receipts relative to output are about 4.4% as estimated by CBO for 2017, OASDI bases are scaled uniformly across individuals.

Finally, to ensure that the internal tax calculator produces household capital income tax liabilities to output ratios that are consistent with those estimated by the JCT-ITM for each capital income type k, we make use of the base adjustments for each income type as described in Appendix A.2. Table 4 shows the targets and actual outcome of this process in the initial steady state.[24]

3.2.4 Household Taxation with the Conventional Tax Specification

For the labor income tax function in Equation (2.56), the parameters $\{\lambda_1^f, \lambda_2^f\}$ are set in the initial steady state to target an aggregate average tax rate, $\overline{ATR}^f$, and an effective marginal tax rate, $\overline{EMTR}^f$, both at the family-composition level of aggregation computed from the JCT-ITM. The parameters are computed as follows:[25]

[23] The average tax rates are derived by dividing the figures in Table 1 by the corresponding figures in Table 2 for each (f, z) demographic. We report these components separately because, as described in Appendix A.1.1, adjusted gross labor income for each demographic is calibrated internally by choosing individual labor productivity to meet the specified income target.

[24] Since rental income is a relatively small portion of total capital income and receives the same tax treatment as noncorporate business income, the tables combines the two.

[25] See Moore and Pecoraro (2020b) for a derivation.

$$\lambda_1^f = (1 - \overline{ATR}^f)\left(\frac{\int_{\mathbb{Z}}\int_{\mathbb{J}}(\hat{i}_j^{f,z})\hat{\Omega}_j^{f,z}\ dj\ dz}{\int_{\mathbb{Z}}\int_{\mathbb{J}}(\hat{i}_j^{f,z})^{1-\lambda_2^f}\hat{\Omega}_j^{f,z}\ dj\ dz}\right)$$

$$\lambda_2^f = \frac{\overline{EMTR}^f - \overline{ATR}^f}{1 - \overline{ATR}^f}$$

where λ_1^f must be endogenously calibrated given its dependence on household adjusted gross labor income, and the transfers $tra^{f,z}$ are set to zero in the initial steady state. Table 2 shows the labor income tax liabilities generated by this function on average over (f, z) demographics in the initial steady state, with the associated average adjusted gross labor income levels shown in Table 1.

The age group - marital status specific capital income tax rates, $\bar{\tau}_j^{\boldsymbol{k},f}$, are computed from the JCT-ITM as total capital income tax liabilities relative to total capital income included in AGI for each demographic group. Given these exogenous tax rates, a uniform adjustment to gross capital income for all households is calibrated internally as described in Appendix A.2 so that aggregate capital income taxes relative to aggregate output within the initial steady state match the target specified in Table 4.

While payroll taxes on labor income for working age households are calibrated under the CTS in the same fashion as is done under the ITC as described in Section 3.2.3, the special tax treatment of social security income under the CTS is modeled via exogenous average tax rates $\bar{\tau}^{\boldsymbol{SS},f,z}$ computed from the JCT-ITM for each (f, z) demographic. The gross social security income base is scaled uniformly for all households so that social security tax receipts relative to aggregate output matches the target of 0.18% in the initial steady state.

3.2.5 Firm Taxation and Other Taxes

While the taxation of household income differs across tax systems, firm-level taxation is identical under both the ITC and CTS. The set of aggregate effective marginal tax rates, $\{\tau^c, \tau^{nc}, \tau^d, \tau^i, \tau^g\}$, which apply to aggregate corporate income, noncorporate income, dividend income, interest income, and capital gains are exogenously set to those values computed by the JCT-ITM for year 2017. We allow for both the corporate and noncorporate firms to deduct from taxable income their interest expense, accelerated tax depreciation of capital assets, and state and local tax liabilities in the initial baseline through ded^c and ded^{nc}. We endogenously calibrate the lump-sum credit, crd^c and crd^{nc} so that corporate and noncorporate tax liabilities relative to output each match an empirical counterpart for 2017. For the corporate firm we target the tax liability to output ratio of 1.68% estimated by the Congressional Budget Office (CBO) in the *The Budget and Economic Outlook: 2017 to 2027*, and for the noncorporate firm we target a ratio of

1.36% estimated by the JCT-ITM.[26]

The linear federal tax rate on estates, τ^{beq}, is set internally so that the ratio of aggregate estate taxes to output is 0.0012, which is the estimated ratio of estate (and gift) taxes to GDP from the CBO for 2017. The federal transfer payments $trs_j^{f,z}$ consists the sum of a uniform lump-sum net transfer, trl, and conditional welfare transfers, $trw_j^{f,z}$. The lump-sum net transfer is set to be equal to 0.40% of aggregate output, which represents federal transfers (less those for OASI, Medicare, Medicaid, and the outlay portion of tax credits) minus federal excise and miscellaneous taxes. The welfare transfer is to ensure there exists a feasible solution at very low levels of consumable resources in the presence of positive lower bounds on non-housing and housing consumption as in Equation (2.35).

The linear state and local tax rate τ^{sl} is exogenously set to an effective rate of 5.81% on labor income, which represents the greater of state and local tax income or sales tax liabilities for each tax unit as computed by the JCT-ITM for 2017. The state and local property tax rate τ^{slp} is set to $0.0105 \times 0.7174 = 0.0075$, which is the product of the national average property tax rate computed using state-level estimates from the National Association of Homebuilders for 2010-2014, and the average portion of total residential capital that is not consumer durables as reported by NIPA for 2007-2016. Finally, the linear state and local tax rate on corporate income τ^{slc} is internally set to target a ratio of state and local corporate income tax receipts to output 0.0038, which is the 2007-2016 average computed from NIPA estimates.

4 The Portfolio-Effect: An Illustrative Example

To motivate our quantitative analysis in Section 5, consider the stylized case of a hypothetical, high-income single household without children, earning \$200,000 of adjusted gross labor income in 2017. This household would have a federal effective marginal tax rate (EMTR) of 26.37% on ordinary income as computed by the ITC.[27,28] Should this household receive an additional \$25,000 in qualified dividend income, their EMTR on ordinary income will be unaffected because the qualified dividends are preferential capital income and therefore taxed at special low rates as a separate base. If this household instead received an additional \$25,000 in noncorporate distributions, their EMTR on ordinary income would increase to 34.88% because the distributions are treated as ordinary income and taxed jointly with wage income on a progressive tax schedule. With a

[26] Although taxes are not levied directly on the noncorporate firm, the noncorporate firm's behavior must be consistent with the tax liabilities associated with noncorporate income paid at the household level. The only tax liabilities associated with noncorporate income entering the government's budget constraint are those at the household level.

[27] We compute the EMTR by adding 1% to the taxpayer's adjusted gross labor income.

[28] The EMTR is not necessarily statutory tax rate, even if the incremental income used to compute the EMTR does not cause the taxpayer to move across statutory marginal tax brackets.

resulting percent reduction in the marginal after-tax return to labor of -11.56% in the latter case, this household would decrease labor hours by 3.5% assuming a consumption-constant elasticity of 0.30.

In an explicitly intertemporal setting, the household-level behavioral responses also involve timing shifts and a saving decision. To demonstrate how the detailed tax treatment of capital income can affect households' labor and saving choices in this environment, we simulate two examples of one-year shocks to the characterization of capital income. In the first example all capital income is exogenously re-characterized as ordinary income for 2018 (year 1) and taxed jointly with labor income, while in the second example all capital income is re-characterized as preferential capital income and taxed as a separate base for one period. In 2019 (year 2), the ordinary-preferential composition of capital income reverts permanently to its baseline composition.[29] Since the pretax value of every household's adjusted gross capital income remains unchanged, this shock has no effect in the CTS. The impulse responses for the ITC shown in Figure 1 are partial equilibrium, allowing households to re-optimize their lifetime choices following the shock while holding market prices constant at the initial steady state values. The shift to ordinary treatment increases causes the EMTR on ordinary income to increase, resulting an immediate reduction in effective labor supply. Conversely, the shift to preferential treatment decreases the EMTR on ordinary income, resulting in an immediate increase in effective labor supply. In both cases, the stock of savings changes in the same direction as labor supply to reflect the implied consumption-smoothing behavior of households in response to a change in their after-tax lifetime resources.[30]

While these examples represent extreme swings in the tax treatment of household capital income, they highlight the main point of our paper: Careful accounting for the complexity of capital income taxation as under the ITC has implications for household labor supply and savings behavior. In the following section, we show that policy-induced changes to the ordinary-preferential composition of household capital income generate quantitatively significant effects on the macroeconomic aggregates.

5 Policy Experiments

We analyze the general equilibrium transition path following the implementation of two different subsets of tax changes contained in the recently-enacted "Tax Cuts and Jobs Act": (*i*) the corporate rate reduction; and (*ii*) the individual tax provisions. These experiments are performed using the internal tax calculator (ITC) and the conventional

[29]In the baseline steady state, about 66% of total adjusted gross capital income is characterized as ordinary. Since every household has the same portfolio composition, each household then faces the same proportional shock.

[30]If the shock were to persist for a second period, households would have an additional incentive to change their savings in response to changes in the after-tax return to *future* capital income.

tax specification (CTS) each in turn, beginning from an initial steady state associated with 2017 tax law.[31] We report simulation results for the first ten years following the policy change to coincide with the 'budget window' used by the United States Congress to inform legislative decision-making.

The announcement and implementation of policy changes occur in 2018, and are assumed to be unanticipated in 2017. Following the change, agents have perfect foresight regarding the future time path of policy and the economy. Federal budget deficits or surpluses generated by the new policy are financed by borrowing or used to pay down existing debt for the first 30 years following the policy change. To ensure that Federal debt remains on a long-run sustainable debt path as the economy reaches a final steady state, adjustments to non-valued government consumption expenditures made in 2048.[32]

5.1 Policy Experiment 1: TCJA Corporate Tax Rate Reduction

We simulate enactment of the corporate rate reduction as in Title II of JCT (2017), which eliminated the previous-law statutory tax rate schedule on corporate income in the United States with maximum rate of 35% and replaced it with a single 21% statutory rate beginning in calendar year 2018. The conventional revenue target, a loss of $1.349 trillion over fiscal years 2018-2027, is matched under both the ITC and CTS tax systems.[33] While involving only a direct tax change at the corporate level, the policy-induced increase in preferential capital income from an expansion of the corporate sector quantitatively matters for aggregate labor supply and savings responses.

The corporate tax rate reduction causes a major shift in economic activity from the noncorporate sector to the corporate sector, with fully mobile capital and labor reallocating to eliminate any arbitrage opportunities. Figure 2 shows that in both tax systems, an expansion of corporate sector output gives rise to higher dividend payouts and capital gains on corporate equity — both of which are largely treated as preferential income — as well as interest payments from increased borrowing to finance operations. Conversely, the noncorporate sector output contracts and generates a downward trend in distributions[34] — which are treated as ordinary income — as well as capital losses on noncorporate equity and a reduction in interest payments.

The most important difference arises from corporate equity valuation and the accrual of capital gains. In the first year of the new policy regime, capital gains on corporate

[31] See Appendix A.3 for a description of how each tax system is calibrated for policy changes.

[32] Delayed adjustment of fiscal instruments to maintain fiscal sustainability minimizes the within-budget-window bias associated with the specific 'fiscal closure' rule chosen. See Moore and Pecoraro (2020a) for a discussion.

[33] The conventional revenue target from JCT (2017) is the estimated change in tax receipts from those projected under a present-law baseline forecast, holding constant gross national product. See JCT (2011) for a discussion of the conventional estimation methodology.

[34] Noncorporate distributions increase immediately before a long-run decline because the noncorporate firms' investment expenses decline faster than noncorporate output itself.

equity increase by 3.3% under the ITC, but increase by only 0.8% under the CTS. This outcome is a result of general equilibrium effects associated with a relatively higher effective (productivity-weighted) labor supply response under the ITC, shown in Figure 4, which immediately raises the present discounted value of corporate firms. The policy-induced changes to the ordinary-preferential composition of adjusted gross capital income are shown in Figure 3, which result from the portfolio rebalancing undertaken by financial intermediary on behalf of households. While ordinary capital income initially increases before a long-run decline under both tax systems because of the behavior of noncorporate distributions, only under the ITC does preferential capital income increase as a result of the different path of corporate capital gains under that tax system.

Key among the projected paths of aggregates and prices in Figure 4 is the relatively larger accumulation of deposits and increase in effective labor supply under the ITC. The gradual movement of economic activity into the corporate sector results in an increase in the preferential share of capital income over time that encourages households to accumulate relatively more deposits because more capital income is taxed at lower rates. Similarly, the gradual reduction in ordinary capital income will result in a smaller EMTR on labor income, especially for wealthier households who tend to have high quantities of capital income and relatively higher labor productivity. This leads to effective labor supply increases that grow over time. Contrast this with the behavior of labor supply under the CTS, which remains largely unchanged until 2023 when capital deepening sufficiently raises the real wage rate.[35]

5.2 Policy Experiment 2: Individual Tax Provisions of TCJA

We simulate enactment of the individual tax provisions in Title I of JCT (2017), most of which became effective beginning in 2018 and are scheduled to expire in 2025. Key among these provisions, all of which are modeled explicitly within the ITC, are an overall reduction in statutory tax rates on ordinary income, expansion of the standard deduction, modification of itemized deductions, 20% deduction of qualified business income for pass-through entities, repeal of personal exemptions, and expansion of the child tax credit. The total conventional revenue loss of these tax changes was estimated to be $1.126 trillion over fiscal years 2018-2027 in JCT (2017), which is matched under both the ITC and CTS tax systems. The main finding here is that the policy-induced increase in households' labor supply endogenously generates a change to the composition of capital income towards preferential in the short-run, which itself feeds back into household behavior and leads quantitative differences in the path of economic aggregates.

Figure 7 shows the response of select economic aggregates and prices over the budget

[35] Under the CTS, productivity un-weighted labor hours increase throughout the budget window while productivity weighted labor supply remains roughly constant. This results from the initial labor supply response being largely driven by low-productivity workers under that tax system.

window. Although qualitatively similar, there are substantial differences in magnitudes across the ITC and CTS simulations. The relatively larger effective labor supply increase under the ITC tax system drives the relatively larger increase in aggregate output. Increased output leads to more capital income flowing from firms to households; figure 5 shows that the increase in each type capital income is substantially larger under the ITC. Figure 6 shows this result in terms of its impact on the ordinary-preferential composition of household capital income. An immediate increase in preferential capital income, resulting from the substantial increase in capital gains, eventually gives way to a more sustained increase in ordinary capital income as noncorporate distributions grow until the tax provisions expire in 2026.

The relatively larger response of labor supply under the ITC is an outcome of a self-reinforcing equilibrium relationship between firm equity value and labor supply that is present when accounting for the detailed tax treatment of household capital income: Firms that foresee the increase in future output — following from additional labor input — experience an immediate increase in their present discounted value that results in a capital gain for households who hold equity. Because capital gains are largely treated as preferential capital income, this additional income is taxed separately from labor income at low rates. Households foresee that this increase in preferential capital income is temporary, and shift their labor supply towards these when EMTR on labor income is relatively lower.

As with the corporate rate reduction, households' accumulation of savings deposits is substantially higher in the ITC than in the CTS despite similar levels of productive capital accumulation by firms. While additional incentives to save in taxable financial wealth under the ITC arise from the changing composition of capital income, all flows of new savings are not immediately invested into productive capital in our model with explicit firm financing. In the market-clearing equilibrium, the quantity of savings deposits must be sufficiently large to support the quantity of outstanding equity, bonds, and rental housing. Because the value of private equity immediately increases by substantially more under the ITC as described above, the borrowing rate increases to clear the market, discouraging firms from issuing additional bonds to finance capital investment.

5.3 Limitations

We have shown that when accounting for the detailed taxation of household income, changes to the ordinary-preferential composition of capital income has quantitatively significant implications for household labor and saving behavior. However, our study is not without limitations. First, throughout this paper we have maintained the implicit assumption that households within our model do not vary in the extent to which savings are held in tax-deferred or tax-preferred accounts. Because lifecycle variation in the utilization of these savings vehicles will affect the size of households' income tax bases differently at different ages, their incorporation within the modeling framework has the potential to affect the effective marginal tax rates relevant for labor and savings decisions and thus macroeconomic outcomes. Second, since the financial intermediary determines the composition of capital assets held by households, the portfolio is optimal only in the aggregate. Possible directions for future research are to incorporate special savings vehicles and heterogeneous portfolios along with the tax detail introduced in this work.

6 Conclusion

We have argued that simultaneously accounting for the joint taxation of ordinary income and the special taxation of preferential income as in the United States generates a 'portfolio-effect' mechanism, whereby changes to the ordinary-preferential composition of households' capital income can influence individuals' optimal labor and saving decisions through its impact on their effective marginal tax rates. To explore this mechanism, we used a heterogeneous-agent overlapping generations model with a two-entity production sector and an internal tax calculator to simulate two subsets of tax provisions in the 'Tax Cuts and Jobs Act': i) the corporate tax rate reduction; and ii) the individual tax provisions. In both cases, changes to the pattern of investment across corporate and non-corporate sectors result in endogenous changes to the composition of households' capital income which affect their labor and saving incentives. This portfolio effect was found to be sufficiently strong to affect the path of aggregate labor supply and savings. Consequentially, failure to account for the complexity of household capital and labor income taxation when modeling a tax reform risks the omission of an important mechanism from the analysis.

7 Tables and Figures

Table 1: Average Adjusted Gross Labor Income in Steady State Baseline (in thousands of 2018$)

	Target	**ITC**	**CTS**	**Target**	**ITC**	**CTS**
Productivity Type	Single Households			Married Households		
1	0.6	0.6	0.6	16.2	16.4	16.3
2	11.9	11.9	12.1	51.2	51.4	51.6
3	25.8	25.6	26.1	82.8	82.7	83.3
4	44.6	44.8	44.8	119.4	119.1	120.3
5	97.4	97.4	98.4	279.6	279.7	282.0

Table 2: Average Labor Income Tax Liability in Steady State Baseline (in thousands of 2018$)

	Target	**ITC**	**CTS**	**Target**	**ITC**	**CTS**
Productivity Type	Single Households			Married Households		
1	-0.1	-0.1	-0.5	-2.0	-2.0	-3.2
2	-2.0	-2.1	-1.9	0.7	0.8	0.5
3	-1.3	-1.3	-1.7	5.6	5.5	4.9
4	2.8	2.8	2.3	11.9	11.9	13.1
5	14.7	14.6	16.1	57.1	57.0	60.0

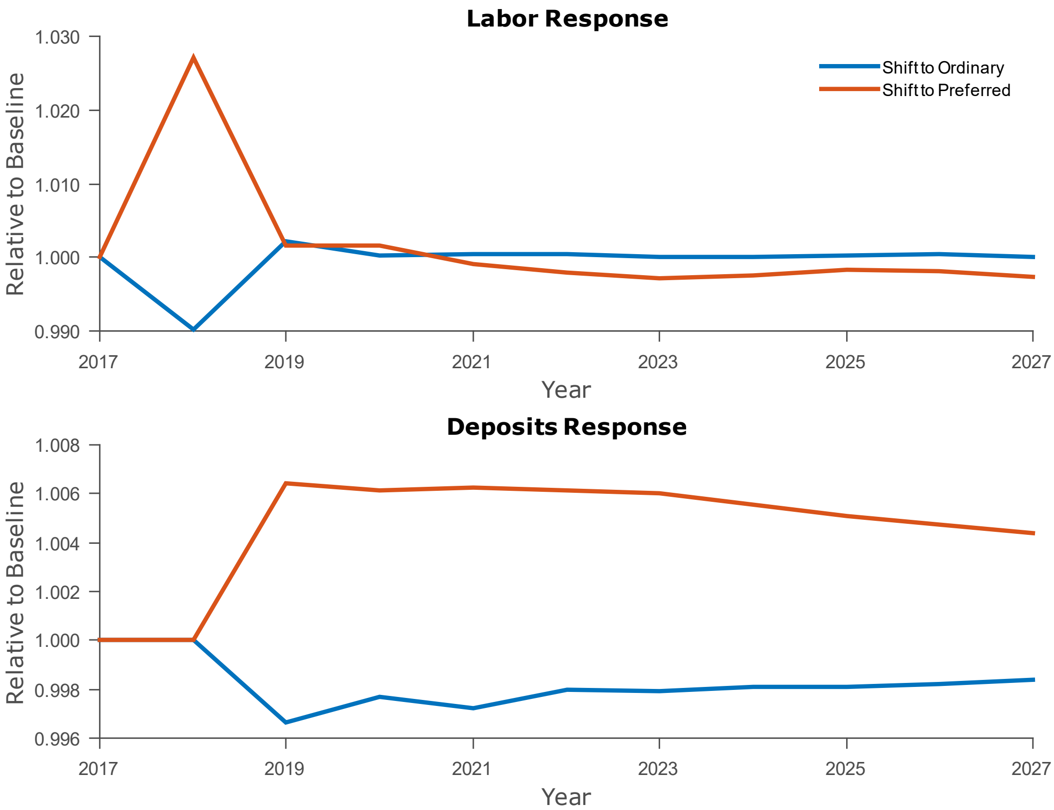
Table 3: Capital Income Decomposition

	Ordinary				
	Corporate Dividends	Noncorporate Distributions	Interest Income	Capital Gains	Rental Income
ITC	2.8%	20.9%	10.7%	4.5%	2.4%
CTS	2.5%	20.5%	10.2%	4.7%	2.1%
	Preferential				
	Corporate Dividends	Noncorporate Distributions	Interest Income	Capital Gains	Rental Income
ITC	8.4%	0%	7.1%	43.2%	0%
CTS	8.4%	0%	6.8%	44.5%	0%

Table 4: Aggregate Capital Income Tax Ratios in Steady State Baseline

Target Ratio	**Target**	**ITC**
Noncorporate distribution taxes to aggregate output ratio	0.0136	0.0136
Corporate dividend taxes to aggregate output ratio	0.0021	0.0021
Interest income taxes to aggregate output ratio	0.0008	0.0005
Capital gains taxes to aggregate output ratio	0.0067	0.0067
Target Ratio	**Target**	**CTS**
Total capital income taxes to aggregate output ratio	0.0221	0.0229

Figure 1: Impulse Response of Labor and Deposits: Illustrative Example



7.1 TCJA Corporate Rate Reduction

Figure 2: Changes to Economic Activity by Sector: TCJA Corporate Rate Reduction

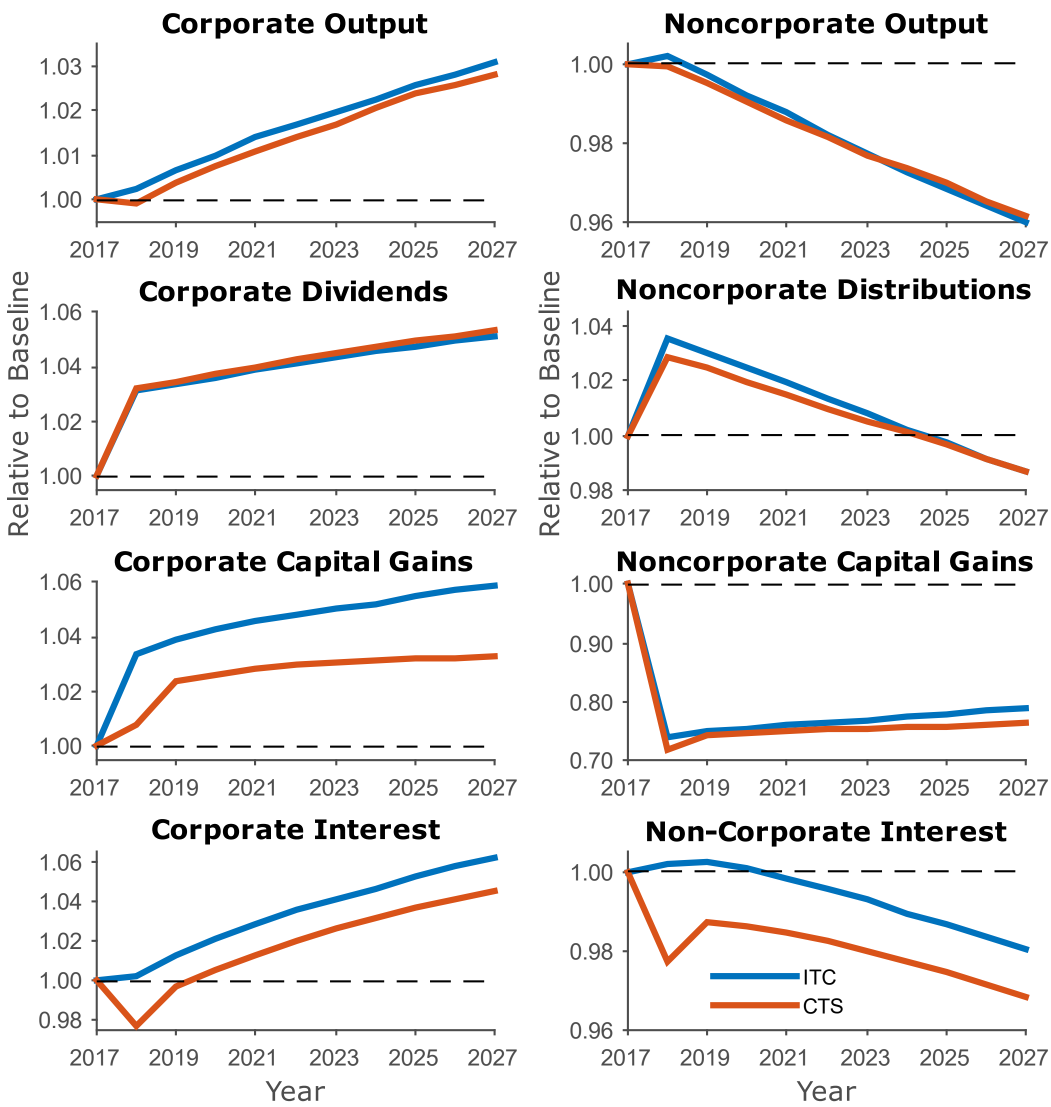


Figure 3: Changes to Portfolio Composition: TCJA Corporate Rate Reduction

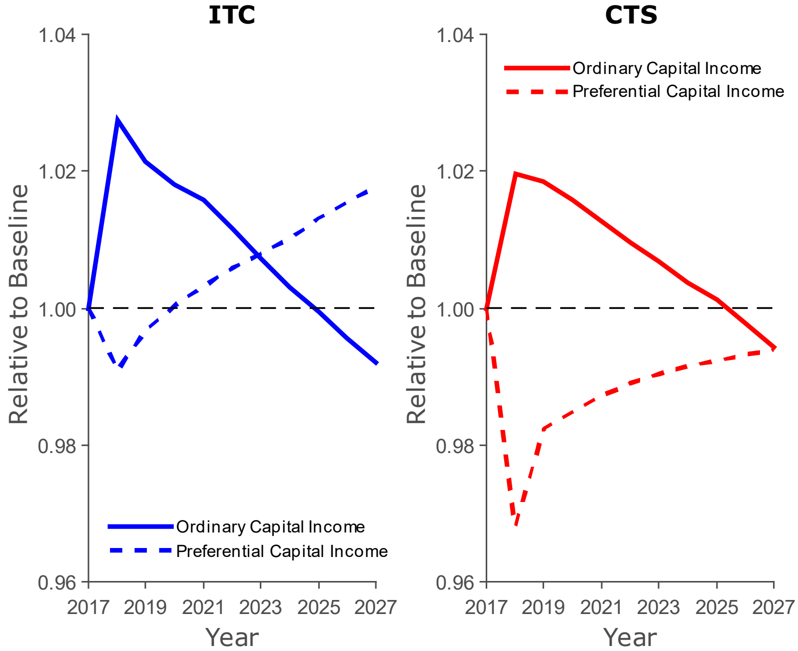
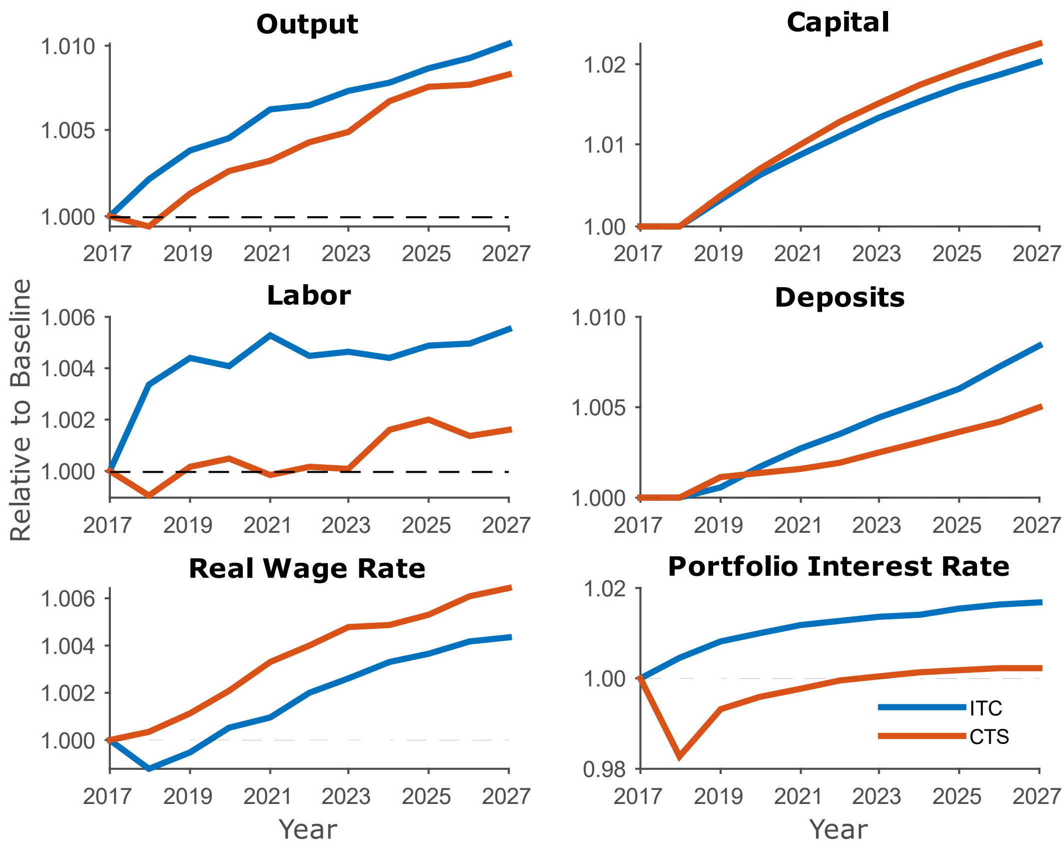


Figure 4: Changes to Key Aggregates: TCJA Corporate Rate Reduction



7.2 Individual TCJA Provisions

Figure 5: Changes to Economic Activity by Sector: Individual TCJA Provisions

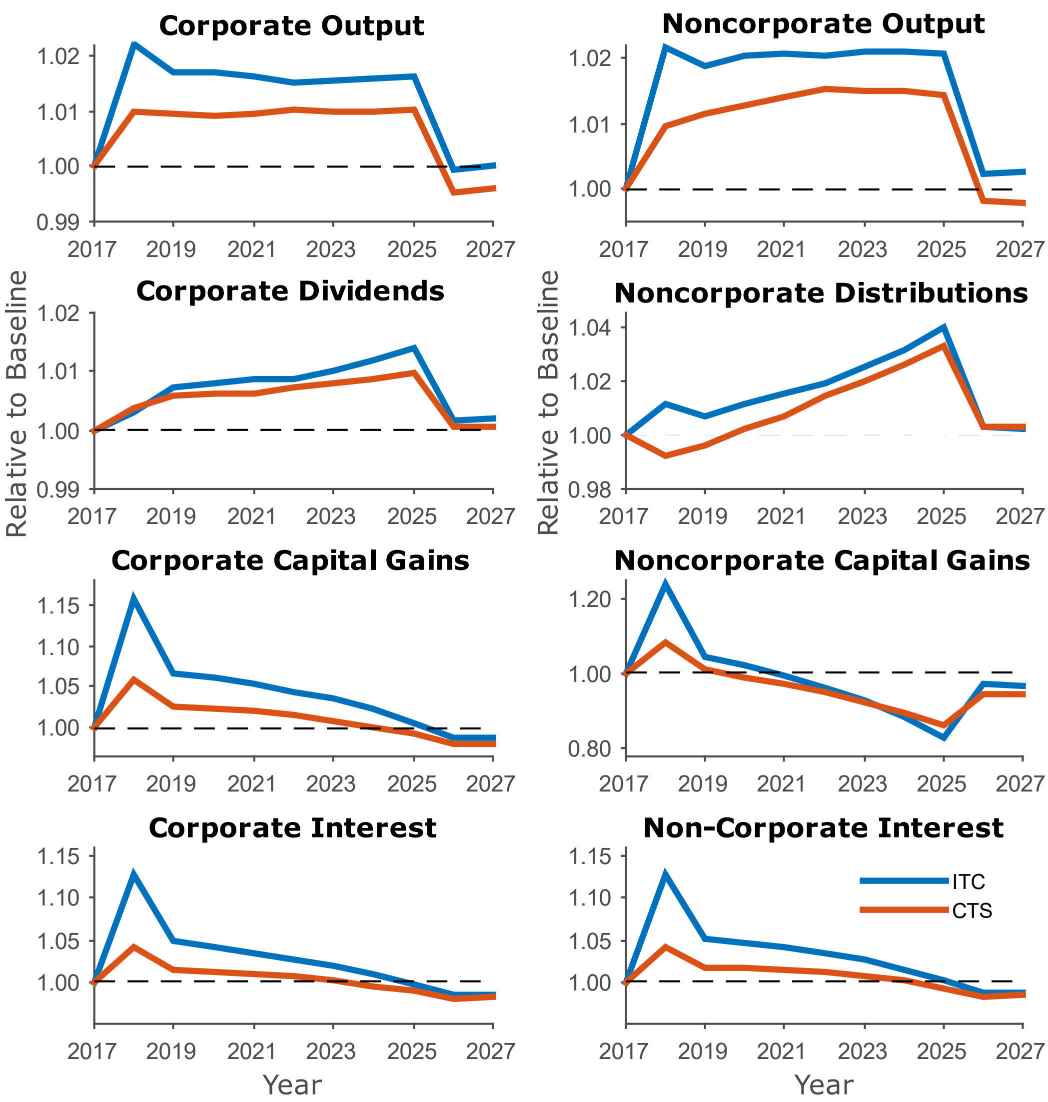


Figure 6: Changes to Portfolio Composition: Individual TCJA Provisions

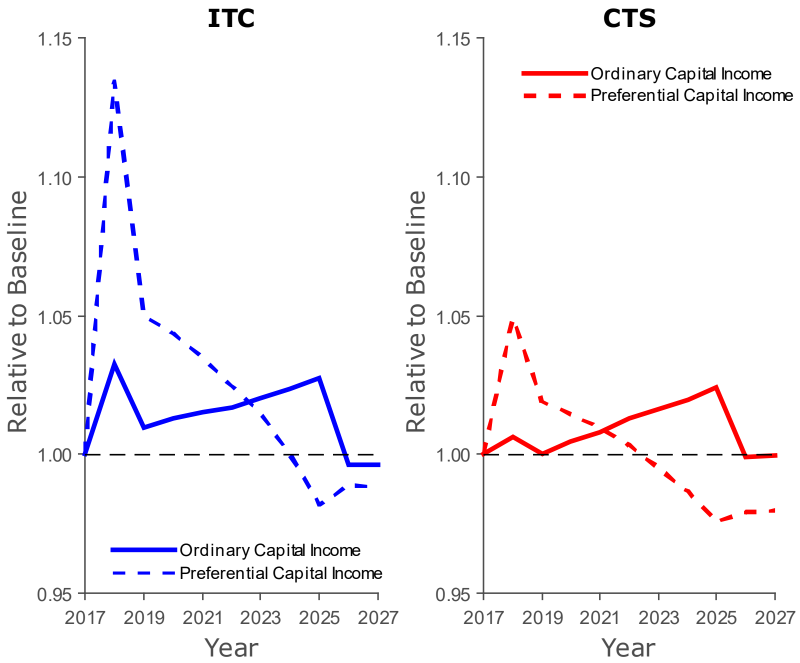
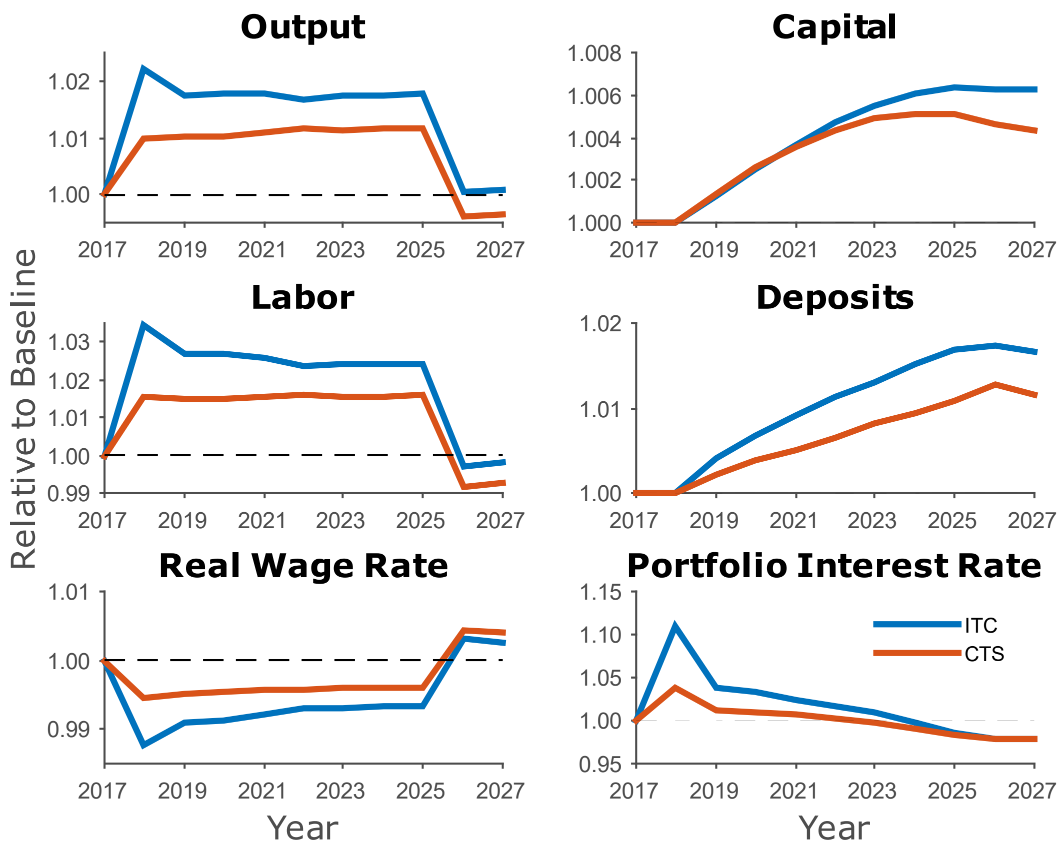


Figure 7: Changes to Key Aggregates: Individual TCJA Provisions



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Appendices (for online publication)

A Calibration

A.1 Non-Tax Policy Parameters Values and Targets

A.1.1 Household Demographics, Preferences, and Characteristics

As the household sector of our model utilizes the framework developed in Moore and Pecoraro (2020b), the calibration strategy for household demographics, preferences, characteristics generally follows that described in Appendices A.1.1, A.1.3, and A.2 of that work. However, since we currently specify an initial year of 2017 instead of 2018,[1] both the exogenously and endogenously calibrated parameter values may vary from Moore and Pecoraro (2020b) despite the same calibration strategy and targets, key of which are reported in Tables A2 and A3. For this reason Table A1 contains the currently used values for the same set select exogenous parameters reported in the earlier work. Only the deviations from the prior calibration strategy for the household sector made in this paper are described below.

The instantaneous utility function in this paper accounts for the effect of children at home on the supply of market labor hours in the spirit of Guner et al. (2011) and Borella et al. (2019). We specify an additive product along with labor hours in the disutility for labor function, $\varphi\nu_j^{f,z}$, meant to capture the interaction between lifecycle disutility of work and the presence of children. We let $\nu_j^{f,z}$ be the number of dependents under the age of 6 for a given (j, f, z) demographic, which are calculated using the JCT-ITM for 2017. The parameter φ is set equal to 0.094 so that parents spend about 520 hours per child each year, (Hotz and Miller, 1988), which is broadly consistent with the time value specified by Guner et al. (2011).

The amount of hours spent on home production have a fixed, inverse relationship to the amount of market labor hours. We use the 2017 *American Time Use Survey* to compute the average hours spent working in full-time and part jobs for all workers, and the 2013-2017 average for hours spent doing 'household activities' for full time, part time, and unemployed individuals by worker type (single, married primary, married secondary). Normalizing available (non-sleep) time to unity yields the following mapping from market work hours to home work hours:

$$\mathbb{N} = [0.000, 0.211, 0.422] \rightarrow \begin{cases} \mathbb{NH} & = [0.180, 0.135, 0.101] \text{ if } f = s \\ \mathbb{NH} & = [0.153, 0.109, 0.084] \text{ if } f = m, 1 \\ \mathbb{NH} & = [0.252, 0.181, 0.124] \text{ if } f = m, 2 \end{cases}$$

Empirically, the value of home production has been measured by multiplying hours spent on housework by the wage rate of domestic workers (Bridgman, 2016). We take a similar approach to calculating the value of home production as a function of non-work hours:

[1] Parameters calibrated to the single year 2018 in Moore and Pecoraro (2020b) are calibrated to the single year 2017 here, while parameters calibrated from 2018-2028 projections in the former paper are calibrated from 2017-2027 projections presented in *The Budget and Economic Outlook: 2017 to 2027.*

$$ch(nh_j^f) = \begin{cases} w_t\bar{z}^{s,1} nh_j^s & \text{if } f = s \\ w_t\bar{z}^{s,1}(nh_j^{m,1} + nh_j^{m,2}) & \text{if } f = m \end{cases}$$

where $w_t\bar{z}^{s,1}$ is the average wage rate for the lowest productivity type single household.

We define labor income to be equal to the NIPA-comparable wage concept used Moore and Pecoraro (2020b).[2] That is, we do not include a share of noncorporate income in our labor income definition for purposes of sorting households by labor income productivity as previously specified. Relative to the previously used composite income concept, we can better account for the joint tax treatment of business and wage income because our current framework allows for the explicit decomposition of capital income across different types. Figure 1 shows the initial steady state labor income targets, $\bar{i}^{f,z}$, and the model fit for both the ITC and CTS. The targets are matched in the model under both tax systems by internal calibration of the permanent level component of labor productivity.

Households who die before reaching the maximum age J leave behind estates after end-of-life expenditures, c_t^{eol}, which are computed as a residual from equation (2.39). Given the endogenous end-of-period net worth of dying households and the exogenous tax rate τ_t^{beq}, the exogenous distribution of bequests that aggregates to $\bar{\Lambda}$ must be specified so that c_t^{eol} can be computed. First, we assume that all bequests are received by households entering the economy at age $j = 1$ as endowments of initial financial wealth a_1, and allow for variation in this dimension over each (f, z) demographic indexed by $e = \{1, \ldots, ne\} \in \mathbb{E}$. To derive this distribution we compute the mean and standard deviation of each net worth[3] quintile for 24-26 year old single and married individuals respectively from a truncated sample of the 1989-2016 waves of the *Survey of Consumer Finances*.[4] We obtain the following mean and standard deviations for single and married household quintiles:

$$\bar{x}^s = \{-2304, 731, 5628, 15185, 51054\}$$
$$\bar{x}^m = \{1845, 7252, 15606, 33219, 83852\}$$

[2]Our 'NIPA-comparable' measure is computed using the JCT-ITM by adding to AGI wage income (*i*) combat pay, (*ii*) employers' share of the FICA tax, (*iii*) deferred 401k compensation, (*iv*) employers share of 401k compensation, (*v*) employer provided dependent care, (*vi*) employer health-insurance compensation, (*vii*) employer HSA compensation, and (*viii*) employer life-insurance compensation.

[3]We define financial wealth as financial assets (balances of checking accounts, savings accounts, money market mutual accounts, call accounts at brokerages, prepaid cards, certificates of deposits, total directly-held mutual funds, stocks, savings and other bonds, IRAs, thrift accounts, future pensions, cash value of whole life insurance, trusts, annuities, managed investment accounts with equity interest and miscellaneous other financial assets) less debt (credit card balances, educations loans, installment loans, loans against pensions and/or life insurance, margin loans and other miscellaneous loans).

[4]We truncate the sample by disregarding all observations in the bottom 20% and top 10% of the original sample. We truncate the sample from the bottom because the magnitude of negative net worth of held by households in the bottom 20% of the original sample prevents the corresponding model agents from feasibly earning enough income to pay off their endowment of debt given the deterministic labor productivity path, thereby violating the no-Ponzi condition. We truncate the sample from the top because the variation in positive net worth held by agents in the top 10% of the distribution requires that the net worth grid be impractically large, generating untenable curse of dimensionality issues.

$$s^s = \{1369, 872, 1885, 3738, 15916\}$$
$$s^m = \{1433, 1961, 3131, 7029, 23905\}$$

For each quintile and marital status combination, we draw $ne = 20$ pseudorandom numbers from standard normal distribution with the associated mean and standard deviations. We then set the distribution for each (f, z) demographic by performing an inverse hyperbolic sine transformation to these draws. It is assumed that this distribution is time-invariant and aggregates to:

$$\bar{\Gamma} = \sum_{f=s,m} \int_{\mathbb{Z}} \int_{\mathbb{E}} a_{j=1}^{f,z,e} \Omega_{t,j=1}^{f,z} \Omega^e \; de \; dz$$

where $\Omega^e = \frac{1}{ne}$ is the measure of endowment level e. While this variation in endowment level does not change the dynamic optimization problem, endowment heterogeneity does add an additional layer of aggregation such that for any variable x:

$$\mathrm{x}_{t,j}^{f,z} = \int_{\mathbb{E}} \mathrm{x}_{t,j}^{f,z,e} \Omega^e \; de$$

Therefore in each year of the simulation, $nf \times nz \times ne$ households enter the model. To reduce notational clutter, we assume this level of aggregation is implicit in our definition of equilibrium in Appendix B.

Finally, we set the lower-bound of the wealth support (the noncollaterized borrowing limit) as the minimum of either the lowest drawn value of endowments for each (f, z) demographic, or negative 10% of the initial steady state target for average annual labor income $\bar{\imath}^{f,z}$:

$$\underline{\mathrm{y}}^{f,z} = \min(\min(a_1^{f,z,e}), -0.1 \times \bar{\imath}^{f,z})$$

A.1.2 Firm Production Technology, Financing, and Housing

As our current specification of firm production technology and the housing sector follow from Moore and Pecoraro (2020b), the calibration strategy for computing parameter values for factor shares, economic depreciation rates, capital adjustment costs, housing transaction costs and minimums remain the same as that described in the Appendix of that paper. Those parameter values are reported in Table A1. The strategy for calibrating the additional parameter values used in our current two-sector framework are described below, and summarized in Table A3.

While the corporate and noncorporate firms are assumed to finance operations with some combination of debt and equity, each representative firm maintains a constant debt to capital ratio $\varkappa^{b,q}$ for $q = c, n$. These parameter values are set to $\varkappa^{b,c} = 0.435$ and $\varkappa^{b,n} = 0.085$ to target an initial steady state ratio of interest expense to aggregate output for the corporate and noncorporate sectors of 0.039 and 0.003, which are computed from the SOI and NIPA for 2016.

While distributions of pass-through income to households from the noncorporate firm are computed as a residual from the noncorporate firm's cash flow equation, the corporate firm distributes dividends to households as a $\varkappa^d$ portion of after-tax earnings. This parameter is set to $\varkappa^d = 0.15$, which targets the ratio of net dividends of domestic C-corporations to aggregate output of 0.031 as measured by NIPA for 2016.

So that the model can reproduce the relative sizes of output produced by corporate and noncorporate sectors, we incorporate time-invariant scale parameters Z^q for $q = c, n$ on the firms' production functions. Targeting the ratio of corporate gross receipts to total business gross receipts equal to 0.692 as computed from the SOI for 2016, we set $Z^c = 1.03$ and $Z^n = 1$.

A.1.3 Government: Public Capital and Debt

The level of productive public capital is set endogenously so that the initial steady state ratios of federal and state-local public capital to output are 18.4% and 55.1%, which are the average observed values over 2007-2016 from NIPA.

The rate of return on public debt is parameterized function of the federal debt-output ratio and the private bond real interest rate. The parameter ς determines the response of this interest rate to changes in the debt-output ratio, and is set equal to 0.1910, which implies that the interest rate increases by 2.5 basis points for every 1 percent increase in the debt-output ratio from its steady state value (Gamber and Seliski, 2019). The parameter ϖ determines the response to changes in the private bond real interest rate and is set so that, given ς and the steady state debt-output ratio, net interest payments relative to output in the initial steady state match the average value projected over 2017-2027 in *The Budget and Economic Outlook: 2017 to 2027*, which is 2.1%.

A.2 Adjustments to Economic Income

To account for differences between personal economic income and adjusted gross income (Ledbetter, 2007), we use 'calibration ratios' to scale each particular flow of economic income which may be subject to taxation.[5] All calibration ratios are assumed to be time-invariant, but may exogenously be changed in response to policy.

Under both the ITC and CTS tax systems, adjusted labor income is obtained from labor income in the same fashion. For working-age households adjusted gross labor income, $\hat{i}^{f,z}_{t,j}$, comes from wage income, for which we apply an (f, z) demographic specific calibration ratio, $\chi^{\boldsymbol{w},f,z}$:

$$\hat{i}^{f,z}_{t,j} \equiv \begin{cases} \chi^{\boldsymbol{w},s,z}\left(n_j w_t \mathrm{z}^{s,z}_j\right) & \text{if} \quad j \leq R \text{ and } f = s \\ \chi^{\boldsymbol{w},m,z}\left((n^1_j + \mu^z n^2_j) w_t \mathrm{z}^{m,z}_j\right) & \text{if} \quad j \leq R \text{ and } f = m \end{cases}$$

For retired households adjusted gross labor income comes from social security income, for which we apply a single calibration ratio, $\chi^{\boldsymbol{SS}}$, for all households:

$$\hat{i}^{f,z}_{t,j} \equiv \chi^{\boldsymbol{SS}} ss^{f,z}_{t,j} \quad \text{if} \quad j > R$$

Adjusted gross capital income, $r^p_t \hat{a}^{f,z}_{t,j}$, is obtained from total capital income in a different manner across the ITC and CTS tax systems because we must distinguish between ordinary and preferential capital income under the former to determine tax liabilities. Letting $s^{\boldsymbol{o}}_{t,k}$ and $s^{\boldsymbol{p}}_{t,k}$

[5]See Altshuler et al. (2005) for a discussion of calibration ratios.

denote the share of each gross capital income type k to be treated as ordinary and preferential respectively, then:

$$r_t^p \hat{a}_{t,j}^{\boldsymbol{o},f,z} \equiv r_t^p \left(\sum_k \chi_k s_{t,k}^{\boldsymbol{o}} \right) a_{t,j}^{f,z}$$

$$r_t^p \hat{a}_{t,j}^{\boldsymbol{p},f,z} \equiv r_t^p \left(\sum_k \chi_k s_{t,k}^{\boldsymbol{p}} \right) a_{t,j}^{f,z}$$

where χ_k is a calibration ratio for each particular capital income type k, and the aggregate consistency condition $\Sigma_k \left(s_{t,k}^{\boldsymbol{o}} + s_{t,k}^{\boldsymbol{p}} \right) = 1$ is imposed. Total adjusted gross capital income is then the sum of $r_t^p \hat{a}_{t,j}^{\boldsymbol{o},f,z}$ and $r_t^p \hat{a}_{t,j}^{\boldsymbol{p},f,z}$. Under the CTS adjusted gross capital income is obtained by applying the single calibration ratio, $\chi^{\boldsymbol{K}}$, to gross capital income:

$$r_t^p \hat{a}_{t,j}^{f,z} \equiv r_t^p \chi^{\boldsymbol{K}} a_{t,j}^{f,z}$$

In both tax environments, capital income calibration ratios do not depend on household age. We therefore abstract from lifecycle heterogeneity in the extent to which savings are held in tax-preferred or tax-deferred accounts.

The wage income calibration ratios are set exogenously as the ratio of wage income included in AGI to NIPA-comparable wage income as described in Appendix A.1.1, and are computed by the JCT-ITM for each (f, z) demographic. The remaining calibration ratios are uniform across all demographics and internally calibrated in the initial steady state to match aggregate tax revenue to output targets computed by the JCT-ITM: The social security calibration ratio is set so that aggregate social security tax receipts relative to output is 0.18%. The capital calibration ratios are set to match the targets listed in Table 4, where for the ITC tax system it is assumed that for each capital income type the portion of aggregate tax revenue attributable to being taxed at ordinary (preferential) rates is proportional to the share of that income type that is treated as ordinary (preferential).[6]

A.3 Calibrating Tax Instruments for Policy Changes

Both the ITC and CTS are calibrated for a given policy change by adjusting the relevant tax instruments while holding constant income, aggregates, and choice variables associated with the initial steady-state present-law equilibrium. The revenue effect achieved within the model is thus consistent with the notion of a 'conventional revenue effect'.[7] For each policy experiment in this paper, we target the associated revenue effect over 2018-2027 as reported in JCT (2017).

While the changes to the taxation of household income differ across tax systems as described below, tax changes at the firm level are made identically under both the ITC and CTS. Specif-

[6]Since rental income is a relatively small portion of total capital income and receives the same tax treatment as noncorporate business income, the tables combines the two.

[7]The conventional revenue effect is the estimated change in tax receipts from those projected under a present law baseline forecast, holding constant gross national product. See JCT (2011) for more details.

ically, we change the aggregate marginal tax rates on corporate income, noncorporate income, interest income, capital gains, and dividends in the model to target the portion of the total conventional revenue effect due to each respective change. For example, if the portion of the total conventional revenue effect due to the corporate rate reduction is some x dollars over the budget window, the marginal tax rate τ_t^c is changed to generate a within-model revenue effect of x dollars over the budget window, holding the initial baseline equilibrium corporate tax base constant. Any changes to deductions and credits allowed to firms are made in a similar manner.

A.3.1 Internal Tax Calculator

Changes to the taxation of household income under the ITC are explicitly incorporated in the tax calculator as specified in the statutes of the policy change. For example, when calibrating the model for the individual provisions in TCJA, we replace the original statutory tax rate schedule applied to ordinary income in the internal tax calculator with the new statutory tax rate schedule under TCJA. Following the explicit changes made within the tax calculator, we make two further adjustments: First, we adjust transfer payments $tra_t^{f,z}$ as needed to match the distributional changes across (f, z) demographics as projected by the JCT-ITM over the budget window. Second, we adjust the calibration ratios for both ordinary and preferential capital income, $\chi_k^{\boldsymbol{o}}$ and $\chi_k^{\boldsymbol{p}}$, to target the average budget-window revenue effect attributed to each source of capital income. These adjustments ensure that we match the targeted conventional revenue effect at the aggregate level and on average at the (f, z) household demographic level.

A.3.2 Conventional Tax Specification

Changes to aggregate average and effective marginal tax rates applied to household labor income are made by re-parameterizing the Bénabou (2002) tax function to match the changes to $\overline{ATR}_t^f$ and $\overline{EMTR}_t^f$ due to the proposal as projected by the JCT-ITM for each f demographic over the budget window. We allow for the parameters $\{\lambda_1^f, \lambda_2^f\}$ to be time-varying to capture different magnitudes of these aggregate rate changes over the budget window. The transfers $tra_t^{f,z}$, set to zero in the initial baseline under the CTS, are set to target the distribution of the conventional revenue effect across (f, z) demographics as projected by the JCT-ITM. Changes to the taxation of household capital income are made by changing the average tax rates on capital income under the proposal as projected by the JCT-ITM for each (f, j) demographic over the budget window. We scale the total change in average tax rates using the calibration ratio to match the portion of the total conventional revenue effect due to capital income tax changes.

A.4 Tables

Table A1: Select Exogenous Parameters

Demographics		
Terminal ages	R, J	40, 66
Rate of population growth	υ_P	0.0076
Production		
Rate of technological progress	υ_A	0.0108
Private capital share of output	α	0.3265
Public capital share of output	g	0.0352
Private capital depreciation rate	δ^K	0.0799
Corporate dividend payout ratio	$\varkappa^d$	0.150
Debt-capital ratio	$\varkappa^{b,c}$, $\varkappa^{b,n}$	0.435, 0.085
Output scale parameter	Z^c, Z^n	1.03, 1.00
Private capital adjustment cost parameter	ξ^K	6
Housing		
Owner-occupied housing minimum down-payment	γ	0.20
Housing status adjustment cost	ϕ	0.05
Housing services depreciation rate	δ^o, δ^r	0.0662, 0.1230
Owner-occupied housing minimum (ITC)	$\underline{\mathrm{h}}^o$	1.045
Owner-occupied housing minimum(CTS)	$\underline{\mathrm{h}}^o$	1.08
Preferences		
Subjective discount factor	β	0.985
Non-housing consumption share of composite	σ	0.265
Housing/non-housing consumption substitution parameter	η	-1.053
Utility curvature parameter	$\zeta^{f,\epsilon}$	5
Intensive labor margin disutility (ITC)	ψ^s,$\psi^{m,1}$,$\psi^{m,2}$	$477.0, 291.0, 117.9$
Intensive labor margin disutility (CTS)	ψ^s,$\psi^{m,1}$,$\psi^{m,2}$	$521.1, 324.0, 143.1$
Extensive labor margin fixed cost (ITC)	ϕ^s, ϕ^m	$0.375, 0.220$
Extensive labor margin fixed cost (CTS)	ϕ^s, ϕ^m	$0.548, 0.225$
Children disutility parameter	φ^f	0.094
Government		
Public capital depreciation rate	δ^g	0.0317
Interest rate response to federal debt	ς	0.0145

Table A2: Targeted and Baseline Actual Employment Status by Type of Worker

Type of Worker	**Data** (MEPS)			**ITC**			**CTS**		
	FT	**PT**	**U**	**FT**	**PT**	**U**	**FT**	**PT**	**U**
Single	0.61	0.24	0.15	0.61	0.25	0.14	0.61	0.24	0.15
Married Primary	0.90	0.08	0.02	0.89	0.11	0.00	0.90	0.10	0.00
Married Secondary	0.42	0.32	0.26	0.42	0.33	0.25	0.42	0.32	0.26

Table A3: Targeted and Baseline Actual Aggregate Ratios

Ratio	**Data**	**ITC**	**CTS**
Homeownership ratio	0.639 (AHS)	0.638	0.633
Private business investment to total private investment ratio	0.465 (BEA)	0.470	0.479
Private business investment to output ratio	0.162 (BEA)	0.165	0.170
Corporate gross interest expense to output ratio	0.039 (SOI/BEA)	0.037	0.035
Noncorporate gross interest expense to output ratio	0.003 (SOI/BEA)	0.003	0.003
Corporate net dividends to output ratio	0.031 (BEA)	0.030	0.030
Corporate gross receipts to total business gross receipts ratio	0.692 (SOI)	0.704	0.701

B Trend-Stationary Equilibrium

The model is transformed into trend-stationary form as described in Appendix B.1 of Moore and Pecoraro (2020b) so that a stationary solution method can be used to solve the model. The solution method used here generally follows the algorithm laid out in Appendix C of Moore and Pecoraro (2020b). We define our equilibrium in terms of the transformed model where the tilde accent denotes a variable that has been de-trended for exogenous population and/or technological growth.

For each age cohort, j, productivity type, z, and family composition f, households have ordinary consumption, $\tilde{c}^i$, charitable giving, $\tilde{c}^g$, market labor hours, n, n^1, and n^2, owner-occupied housing services consumption, $\tilde{h}^o$, rental housing services consumption $\tilde{h}^r$, financial wealth $\tilde{a}$, and future net worth $\tilde{y}'$, as control variables. Households have current net worth $\tilde{y}$ as their endogenous individual state variable, and their age, productivity type, as family composition as their exogenous state variables. Household choices of home production $\tilde{c}^h$ and child-care costs $\tilde{\kappa}$ depend exogenously on a household's contemporaneous choice of market labor supply. End-of-life expenditures $\tilde{c}^{eol}$ are determined by the net worth left by households who die at the end each period after taxes and bequests. Bequests are distributed in an exogenous, time-invariant fashion and aggregate to $\tilde{\tilde{\Gamma}}$.

Corporate and noncorporate firms, valued at $\tilde{V}^c$ and $\tilde{V}^n$, have effective labor inputs $\tilde{N}^c$ and $\tilde{N}^n$, and future private capital stocks $\tilde{K}^{c'}$ and $\tilde{K}^{n'}$ as control variables, with current private capital stocks $\tilde{K}^c$ and $\tilde{K}^n$ as state variables.

Endogenous aggregate state variables are effective market labor supply $\tilde{N}$, owner-occupied housing capital $\tilde{H}^o$, rental housing capital $\tilde{H}^r$, deposits $\tilde{D}$, private consumption $\tilde{C}_t$, financial intermediary income $\tilde{Inc}$, private business capital $\tilde{K}$, public capital $\tilde{G}$, private bonds $\tilde{B}$, public bonds $\tilde{B}^g$, and federal, state, and local tax instruments and transfer payments associated with given tax system, the set of which are denoted by $\mathbb{T}$.

Definition 1. *A* ***perfect-foresight trend-stationary recursive equilibrium*** *is comprised of a measure of households $\tilde{\Omega}^{f,z}_{t,j}$, a household value function $V^{f,z}_{t,j}(\tilde{y})$, a collection of household decision rules $\{\tilde{c}^{i;f,z}_{t,j}(\tilde{y})$, $\tilde{c}^{g;f,z}_{t,j}(\tilde{y})$, $n^{z,s}_{t,j}(\tilde{y})$, $n^{z,m,1}_{t,j}(\tilde{y})$, $n^{z,m,2}_{t,j}(\tilde{y})$, $\tilde{h}^{o;f,z}_{t,j}(\tilde{y})$, $\tilde{h}^{r;f,z}_{t,j}(\tilde{y})$, $\tilde{a}^{f,z}_{t,j}(\tilde{y})$; $\tilde{y}^{f,z}_{t+1,j+1}(\tilde{y})\}$, a set of firm values $\{\tilde{V}^c_t(\tilde{K_t}^c), \tilde{V}^n_t(\tilde{K}^n_t)\}$, a collection of firm decision rules $\{\tilde{N}^c_t(\tilde{K_t}^c), \tilde{N}^n_t(\tilde{K_t}^n); \tilde{K}^c_{t+1}(\tilde{K_t}^c), \tilde{K}^n_{t+1}(\tilde{K_t}^n)\}$, prices $\{\tilde{w}_t, p^r_t, R^c_t, R^n_t, i_t, \rho_t, r^p_t\}$, aggregates $\{\tilde{N}_t, \tilde{H}^o_t, \tilde{H}^r_t, \tilde{D}_t, \tilde{C}_t, \tilde{Inc}_t, \tilde{K}_t, \tilde{G}_t, \tilde{B}_t, \tilde{B}^g_t\}$, and the set of tax instruments and transfers $\mathbb{T}$ associated with given tax system such that:*

1. *Household' decision rules are solutions to their constrained optimization problem.*

2. *Macroeconomic aggregates are consistent with household behavior such that:*

$$\tilde{N}_t = \int_{\mathbb{Z}} \int_{\mathbb{J}} \tilde{\Omega}^{z,s}_{t,j} z^{z,s}_j n^{z,s}_{t,j}(\tilde{y}) + \tilde{\Omega}^{z,m}_{t,j} z^{z,m}_j \left(n^{z,1}_{t,j}(\tilde{y}) + n^{z,2}_{t,j}(\tilde{y}) \right) \; dj \; dz$$

$$\tilde{H}^o_t = \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \tilde{\Omega}^{f,z}_{t,j} \tilde{h}^{o;f,z}_{t,j}(\tilde{y}) \; dj \; dz$$

$$\tilde{H}^r_t = \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \tilde{\Omega}^{f,z}_{t,j} \tilde{h}^{r;f,z}_{t,j}(\tilde{y}) \; dj \; dz$$

$$\tilde{D}_t = \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \tilde{\Omega}^{f,z}_{t,j} \tilde{a}^{f,z}_{t,j}(\tilde{y}) \; dj \; dz$$

$$\tilde{C}_t = \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \tilde{\Omega}^{f,z}_{t,j} \left((\tilde{c}^{i;f,z}_{t,j}(\tilde{y}) - \tilde{c}^{h;f,z}_{t,j}) + \tilde{c}^{g;f,z}_{t,j}(\tilde{y}) + \tilde{\kappa}^{f,z}_{t,j} \right) \; dj \; dz + \tilde{c}^{eol}_t$$

3. *Firms' decision rules are solutions to their constrained optimization problem.*

4. *Macroeconomic aggregates are consistent with firm behavior such that:*

$$\tilde{N}_t = \sum_{q=c,n} \tilde{N}^q_t(\tilde{K}_t{}^q)$$

$$\tilde{K}_{t+1} = \sum_{q=c,n} \tilde{K}^q_{t+1}(\tilde{K}_t{}^q)$$

$$\tilde{B}_t = \sum_{q=c,n} \varkappa^{b,q} \tilde{K}_t{}^q$$

5. *Perfectly competitive labor markets clear so that the marginal product of effective labor is equalized across sectors:*

$$\tilde{w}_t = (1-\alpha-g)\tilde{G}^g_t(\tilde{K}^c_t)^\alpha(\tilde{N}^c_t)^{-\alpha-g} = (1-\alpha-g)\tilde{G}^g_t(\tilde{K}^n_t)^\alpha(\tilde{N}^n_t)^{-\alpha-g}$$

6. *The asset market clears such that:*

$$\tilde{D}_t = \tilde{V}^c_t + \tilde{V}^n_t + \tilde{B}^c_t + \tilde{B}^n_t + \tilde{B}^g_t + H^r_t$$

where assets are priced to eliminate any arbitrage opportunities:

$$R^c_t = R^n_t = (1-\tau^i_t)i_t = p^r_t - \delta^r$$

and the financial intermediary is willing to accept 'safe-asset' pricing of federal government bonds so that:

$$\rho_t = \varpi i_t + \varsigma \exp\left(\frac{\tilde{B}^g_t}{\tilde{Y}_t}\right)$$

Furthermore, the rate of return paid to households on deposits is determined by application of a zero profit condition so that:

$$r_t^p = \tilde{D}_t^{-1} \tilde{Inc}_t$$

7. *The goods market clears such that:*

$$\sum_{q=c,n} Z^q (G_t)^g (K_t^q)^\alpha (A_t N_t^q)^{1-\alpha-g} = \tilde{C}_t + \tilde{I}_t + \tilde{\mathcal{G}}_t$$

where private aggregate investment is defined as:

$$\tilde{I}_t \equiv \tilde{I}_t^c + \tilde{I}_t^n + \tilde{I}_t^o + \tilde{I}_t^r + \tilde{\Phi}_t^H$$

with:

$$\begin{aligned}
\tilde{I}_t^c &= \tilde{K}_{t+1}^c (\Upsilon_P \Upsilon_A) - (1-\delta^K)\tilde{K}_t^c + \Xi_t^c \\
\tilde{I}_t^n &= \tilde{K}_{t+1}^n (\Upsilon_P \Upsilon_A) - (1-\delta^K)\tilde{K}_t^n + \Xi_t^n \\
\tilde{I}_t^o &= \tilde{H}_{t+1}^o (\Upsilon_P \Upsilon_A) - (1-\delta^o)\tilde{H}_t^o \\
\tilde{I}_t^r &= \tilde{H}_{t+1}^r (\Upsilon_P \Upsilon_A) - (1-\delta^r)\tilde{H}_t^r \\
\tilde{\Phi}_t^H &= \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \tilde{\Omega}_{t,j}^{f,z} \phi \left(\tilde{h}_{t+1,j+1}^{o;f,z}(\tilde{y}) + \tilde{h}_{t+1,j+1}^{r;f,z}(\tilde{y}) \right) \; dj \; dz
\end{aligned}$$

and where aggregate government expenditures is defined as:

$$\tilde{\mathcal{G}}_t \equiv \tilde{C}_t^{fed} + \tilde{C}_t^{sl} + \tilde{I}_t^{fed} + \tilde{I}_t^{sl}$$

with:

$$\begin{aligned}
\tilde{I}_t^{fed} &= \tilde{G}_{t+1}^{fed} (\Upsilon_P \Upsilon_A) - (1-\delta^g)\tilde{G}_t^{sl} \\
\tilde{I}_t^{sl} &= \tilde{G}_{t+1}^{sl} (\Upsilon_P \Upsilon_A) - (1-\delta^g)\tilde{G}_t^{sl}
\end{aligned}$$

8. *The federal government's debt follows the law of motion:*

$$\tilde{B}_{t+1}^g (\Upsilon_P \Upsilon_A) = \tilde{C}_t^{fed} + \tilde{I}_t^{fed} + \tilde{TR}_t^{fed} - (\tilde{txl}_t^{hh} + \tilde{txl}_t^c + \tilde{txl}_t^{beq}) + (1+\rho_t)\tilde{B}_t^g$$

and maintains a fiscally sustainable path so that:

$$\lim_{k\to\infty} \frac{\tilde{B}_{t+k}^g}{\prod_{s=0}^{k-1}(1+\rho_{t+s})} = 0$$

where federal tax receipts from households, firms, and bequests are:

$$\tilde{txl}_t^{hh} = \int_{\mathbb{Z}}\int_{\mathbb{J}} \sum_{f=s,m} \left(\tilde{\mathcal{T}}_{t,j}^{f,z} + \tilde{trs}_{t,j}^{f,z} - \tilde{slt}_{t,j}^{f,z}\right)\tilde{\Omega}_{t,j}^{f,z} \; dj \; dz$$

$$\tilde{txl}_t^{c} = \tau_t^c\left(\tilde{Y}_t^c - \tilde{w}_t\tilde{N}_t^c - \tilde{ded}_t^c\right) - \tilde{crd}_t^c$$

$$\tilde{txl}_t^{beq} = \tau_t^{beq}(\Upsilon_A)\int_{\mathbb{Z}}\int_{\mathbb{J}}(1-\pi_j)\sum_{f=s,m}\tilde{\Omega}_{t,j}^{f,z}\tilde{y}_{t+1,j+1} \; dj \; dz$$

and transfers are:

$$\tilde{TR}_t^{fed} = \int_{\mathbb{Z}}\int_{\mathbb{J}} \sum_{f=s,m} \left(\tilde{ss}_{t,j}^{f,z} + \tilde{trs}_{t,j}^{f,z}\right)\tilde{\Omega}_{t,j}^{f,z} \; dj \; dz$$

9. *The state and local composite government maintains a balanced budget:*

$$\tilde{slt}_t^{hh} + \tilde{slt}_t^{c} = \tilde{C}_t^{sl} + \tilde{I}_t^{sl}$$

where net state and local tax receipts from households and corporations are:

$$\tilde{slt}_t^{hh} = \int_{\mathbb{Z}}\int_{\mathbb{J}} \sum_{f=s,m} \left(\tau_t^{sl}\hat{i}_{t,j}^{f,z} + \tau_t^{slp}h_{t,j}^o\right)\Omega_{t,j}^{f,z} \; dj \; dz$$

$$\tilde{slt}_t^{c} = \tau_t^{slc}\left(\tilde{Y}_t^c - \tilde{w}_t\tilde{N}_t^c - i_t\tilde{B}_t^c\right)$$

10. *The measure of households is time-invariant:*

$$\tilde{\Omega}_{t+1,j}^{f,z} = \tilde{\Omega}_{t,j}^{f,z}$$

11. *The net worth of households that die before reaching the maximum age J is allocated to end-of-life consumption expenditures, estate taxes, and bequests such that:*

$$\tilde{c}_t^{eol} + \tilde{txl}_t^{beq} + \tilde{\bar{\Gamma}} = (\Upsilon_A)\int_{\mathbb{Z}}\int_{\mathbb{J}}(1-\pi_j)\sum_{f=s,m}\tilde{\Omega}_{t,j}^{f,z}\tilde{y}_{t+1,j+1} \; dj \; dz$$

Definition 2. *A* ***steady-state perfect-foresight trend-stationary recursive equilibrium*** *is a perfect-foresight stationary recursive equilibrium, where every growth-adjusted aggregate variable is time invariant.*