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Modeling the Internal Revenue Code in a Heterogeneous-Agent Framework: An Application to TCJA*

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Abstract

Macroeconomic models used for tax policy analysis often simultaneously abstract from two features of the US tax code: special tax treatment for preferential capital income, and the joint tax treatment of ordinary capital and labor income. In this paper, we explore the extent to which explicitly accounting for these tax details has macroeconomic implications within a heterogeneous-agent model. We do this by expanding the Moore and Pecoraro (2018) overlapping generations model to include distinct corporate and non-corporate firms so that the business income distributed to households can be separated into ordinary and preferred capital income. Household income tax treatment is then determined by an internal tax calculator that fully accounts for interaction among income bases while conditioning on idiosyncratic household characteristics. Relative to a conventional approach where household income taxation is determined by independent labor and capital income tax functions that do not distinguish between ordinary and preferred capital income, we find that our innovations have implications for household behavior and economic aggregates — especially the tax consequences of changes to the returns to labor and capital — when analyzing a subset of tax provisions from the recently enacted "Tax Cuts and Jobs Act". Our findings imply that the abstracting from tax detail may come at the expense of correctly accounting for incentives and estimating macroeconomic responses to tax policy changes.

JEL Codes: C63, E62, H30
Keywords: dynamic scoring; tax policy modeling; heterogeneous agents

*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, taxation of household income is conventionally determined by smooth tax functions that do not condition on household demographics and endogenous tax-preferred choices.[1] These tax functions are typically parameterized using output from a microsimulation outside of the model, and then exogenously imposed on agents within the model. Moore and Pecoraro (2018b) embed an internal tax calculator within a heterogeneous-agent model itself, and show that the conventional framework may oversimplify tax incentives with respect to labor income by failing to capture certain mechanisms realized through non-convexities and conditional tax treatments found in the actual tax code. In response to tax policy changes, the tax function environment can lead to short- and medium-run macroeconomic projections that diverge from an approach that explicitly models the complex tax code.

In this paper, we highlight an additional shortcoming of the conventional approach: There lacks an explicit consideration of the special tax treatment of preferential capital income while simultaneously accounting for the joint tax treatment of ordinary capital and labor income. Examples of heterogeneous-agent models following this conventional approach include Nishiyama (2015), Krueger and Ludwig (2016), and Holter et al. (2019), who consider all capital income received by households as a single base taxed separately from labor income, with an independent tax function or rate determining the tax liability from each source of income. Given the dominance of this approach, there exists little previous work that attempts to incorporate explicit interdependence of capital and labor income taxes. Kitao (2010) assumes capital income taxes are a decreasing linear function of labor income, while DeBacker et al. (2019) allow for non-linearities in the relationship between tax bases. Alternatively, Guner et al. (2011), Guner et al. (2014) and Heathcote et al. (2017) implicitly account for this interdependence by treating labor and capital income as a single base with total tax liabilities determined by a single tax function. None of this work attempts to explicitly account for the special treatment of preferential capital income. Given the importance that policy-makers have placed on macroeconomic analysis of tax policy proposals, especially the revenue consequences of such proposals,[2] the possible implications of alternate modeling choices should be investigated.

We explore the extent to which explicitly accounting for the detailed taxation of labor and capital income has macroeconomic implications. We use a large-scale overlapping generations (OLG) model with an internal tax calculator that explicitly models key tax provisions in the Internal Revenue Code (IRC) applied to household income. In doing so, we expand upon the Moore and Pecoraro (2018b) model by including distinct corporate and non-corporate business entities, where the business income distributed to households is taxed jointly with labor and other sources of capital income. This framework allows us to decompose capital income into corporate dividends, pass-through distributions, interest, and capital gains, ensuring distinction is made between ordinary and preferential income within the tax calculator. The calculator takes into account the tax-exempt status of preferred interest income and the special rate schedule applied to qualified dividends

[1] Easterly and Rebelo (1993), Gouveia and Struass (1994), Bénabou (2002), Li and Sarte (2004) are examples of such tax functions. See Guner et al. (2014) for a recent survey of their usage.

[2] In 2015 the United States House of Representatives adopted a 'dynamic scoring' rule, XIII(8)(b), which was incorporated into a joint Concurrent Budget Resolution for the 114^{th} Congress and reaffirmed in the House for the 115^{th} Congress. This rule requires a point estimate of the revenue effect for certain proposed legislation that incorporates the response of macroeconomic activity.

and gains. Finally, ordinary capital income and labor income are taxed as a single base explicitly according to the following IRC provisions while conditioning on household demographics and tax-preferred consumption choices: the statutory tax rate schedule, 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.

Using the internal tax calculator and a conventional tax specification each in turn within the OLG model, we simulate two different subsets of the tax law changes contained in the recently enacted "Tax Cuts and Jobs Act" (TCJA): (*i*) the individual tax provisions; and (*ii*) the corporate tax rate reduction.[3] We find that the modeling choice for the tax treatment of household income has implications for household savings and labor supply behavior for both policy changes. In the case of the individual TCJA provisions, we find that explicitly accounting for the change to the structure of deductions combined with the joint taxation of labor and ordinary capital income results in a dampened response of productive capital accumulation relative to the conventional tax system. For the corporate tax rate reduction, we find that the explicit distinction between preferred and ordinary capital income results in an optimal portfolio re-balancing which lowers effective tax rates on labor income under joint taxation, generating a larger response of labor supply relative to the conventional tax system. These results are associated with quantitatively meaningful differences across tax systems in economic aggregates, particularly for the tax revenue consequences of changes to the returns to capital and labor. Consequentially, accounting for the detailed taxation of labor and capital income should be considered an important property of heterogeneous-agent models that analyze changes to tax policy.

2 Model

In this section, we describe a large-scale OLG framework that explicitly models key provisions in the IRC for determining the tax treatment of household income. While we utilize the demographic structure and household framework developed in Moore and Pecoraro (2018b), we introduce a two-entity production sector to model distinct corporate and non-corporate businesses. Unlike a consolidated business sector — where capital income is an implicit composite of interest, capital gains, and distributions — the two-entity framework allows for distinct flows of income from corporate dividends, pass-through distributions, interest and capital gains. This is important because it allows for us to explicitly account for the special tax treatment of preferential capital income while simultaneously capturing the joint tax treatment of labor and ordinary capital income.

The basic market structure captures the interaction of households, two representative firms, a representative financial intermediary, and government. Households make savings, consumption, labor, leisure, and residential decisions. The corporate and non-corporate firms hire labor directly from households, financing their capital investments and productive operations through a combination of debt and equity. The financial intermediary pools deposits of financial assets from households to make investments in business debt and equity, consumer debt, mortgage debt, public debt, and rental housing, passing the

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

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. The model is solved using an algorithm similar to that described in Appendix C of Moore and Pecoraro (2018b).

2.1 Demographics and 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 complete specification of the household optimization problem is described in Section 2.2 of Moore and Pecoraro (2018b).[4] For purposes of brevity, we only summarize it here: Households maximize their lifetime utility subject to their budget, borrowing, minimum consumption and housing constraints. They derive utility from market consumption, housing services, home production, and charitable giving while they experience disutility and incur child-care expenses from market work. Housing services are realized from either a rental unit obtained the financial intermediary, or from an owner-occupied home. Home production is generated from hours not spent in market work or leisure. Charitable giving occurs due to a demographic specific warm-glow motive. Households save over their lifecycle by depositing their stock of financial assets with a financial intermediary, who makes investment decisions on behalf of households, passing all returns back to households. While the single household only has one potential wage earner, married households have both a potential primary and secondary earner. Each potential earner in a households must exit the labor market by the time they reach the exogenous retirement age, after which they begin to receive social security payments based upon their lifetime qualified labor income. Upon death at any age less than J, remaining household wealth is exogenously apportioned to end-of-life expenditures and accidental bequests.

2.2 Firms

Goods production occurs in two perfectly competitive sectors, corporate and non-corporate, which differ in terms of tax treatment and the distribution of profits. 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.

[4] The structure of the household optimization problem in this paper is identical to that used in Moore and Pecoraro (2018b). Changes to the calibration strategy are detailed in Section A.1.1.

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 follow Lynde and Richmond (1992), Lansing (1998), and Cassou and Lansing (1998) with our inclusion of public capital as a complement to private inputs in an aggregate production function with constant returns to scale. Since there are then decreasing returns to scale for private factors, we are able to obtain an interior solution with our two firm - 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 non-corporate sector. Corporate and non-corporate labor inputs are then $N_t^c = \Lambda_t^c N_t$ and $N_t^n = (1 - \Lambda_t^c) N_t$ respectively.

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. Furthermore, investment decisions that cause deviations from the steady state rate of capital accumulation generate adjustment costs subject to the convex cost function Ξ_t:

$$K_{t+1}^q = (1 - \delta^K) K_t^q + I_t^q - \Xi_t^q \quad \text{for } q = c, n \tag{2.2}$$

$$\Xi_t^q = \frac{\xi^K}{2} \left(\frac{I_t^q}{K_t^q} - \Upsilon_P \Upsilon_A + 1 - \delta^K\right)^2 K_t^q \quad \text{for } q = c, n \tag{2.3}$$

Finally, it is assumed that the debt portion of total resources used to finance investment in each sector is an exogenous ratio of the private capital stock:

$$B_t^q = \varkappa^{b,q} K_t^q \quad \text{for } q = c, n \tag{2.4}$$

where B_t^q is the beginning-of-period net stock of debt held by the representative firm in sector q. While we assume the debt ratio $\varkappa^{b,q}$ is exogenous, its value may be specified to change in response to particular tax policy changes deemed to influence firm financing decisions.

2.2.1 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_t^c depends on both capital gains gns_t^c and dividend payouts div_t occurring in period t:

$$R_t^c = \frac{(1-\tau_t^g)gns_t^c + (1-\tau_t^d)div_t}{V_t^c} \tag{2.5}$$

where τ_t^g is the aggregate accrual-equivalent tax rate on capital gains, and τ_t^d is an aggregate tax rate on dividends. The value of the representative corporate firm at time t is V_t^c. Capital gains are equal to the change in the value of the firm less the value of new share issues, shr_t:

$$gns_t^c = V_{t+1}^c - V_t^c - shr_t \tag{2.6}$$

The firm's objective is to choose the time path of private capital K_t^c and hire the quantity of effective labor input N_t^c that maximize the firm's value at time t. Rearranging equation (2.5) for V_t^c and solving forward gives the firm's objective function below. Letting $\beta_t^c \equiv \frac{1-\tau_t^g}{R_t^c+1-\tau_t^g}$, 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:

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

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:

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

Similar to the exogenous debt to physical capital ratio, the dividend payout ratio $\varkappa^d$ may be specified to change in response to a new tax policy regime.

Corporate earnings are equal to revenue from production, less wages paid and interest paid on debt:

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

Corporate tax liabilities at the federal level is equal to the federal corporate aggregate effective marginal tax rate, τ_t^c, times the taxable earnings base 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 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:

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

2.2.2 Non-corporate Sector

While the non-corporate firm explicitly issues debt in a similar fashion to the corporate firm, shares of equity in the non-corporate firm are implicit in net distributions, dst_t. Net distributions additionally incorporate the portion of earnings that are passed through to firm's owners 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 non-corporate 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 non-corporate firm:

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

Similar to the corporate firm, the objective function of the non-corporate 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 non-corporate 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

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

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 non-corporate income txl_t^n is equal to the non-corporate aggregate effective marginal tax rate, τ_t^n, times the taxable earnings base 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 non-corporate 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, non-corporate distributions are passed through to the household-level where they are taxed jointly with households' other income and collected by the government. A description of our method for incorporating these tax liabilities at the household level is discussed in Section 2.4.

2.3 Financial Intermediary

The financial sector is perfectly competitive, consisting of an arbitrarily large set of infinitely-lived financial intermediaries with the technology to pool savings from households and invest in financial assets and rental property. The sector is summarized here with a representative intermediary, which will be liable to households for beginning-of-period deposits D_t plus a portfolio return $D_t r_t^p$, and will collect new deposits D_{t+1} for which it decides an investment allocation. These new deposits may be allocated across corporate and non-corporate equity V_{t+1}^c and V_{t+1}^n, corporate and non-corporate bonds B_{t+1}^c and B_{t+1}^n, federal government bonds B_{t+1}^g, and rental housing property H_t^r. The equations of motion for the stock of rental housing and bond holdings are as follows:

$$H_t^r = (1-\delta^r)H_{t-1}^r + I_t^r \tag{2.19}$$
$$B_{t+1}^q = B_t^q + \Delta B_t^q, \qquad q = c, n, g \tag{2.20}$$

where investment in rental housing chosen by the financial intermediary is denoted I_t^r, and net bonds purchased by the intermediary from the government, corporate, and non-corporate firms are denoted $\Delta B_t^q,\ q = c, n, g$.

While corporate and non-corporate bonds yield a pretax rate of return of i_t, we assume that investment in government bonds yields a low, "safe" pretax rate of return ρ_t, which depends positively on the change to the federal deficit to output ratio from the corresponding steady state value:

$$\rho_t = \varpi + \varsigma \exp\left(\frac{\Delta B_t^g}{Y_t} - \frac{\Delta B_{SS}^g}{Y_{SS}}\right) \tag{2.21}$$

The intermediary rents current housing services at a price of p_t^r and incurs expenses from the economic depreciation of last period's rental housing capital at rate δ^r.

The intermediary directly holds equity and bonds in both the corporate and non-corporate sectors, as well as government bonds and rental housing assets, all of which are financed by household deposits. As a result, the intermediary's income includes dividends, distributions, capital gains, interest from bond holdings, and rent payments net of economic depreciation. Expenses include the purchase of new debt, equity or rental housing, plus the beginning-of-period principal and return on deposits remitted back to households.

For notational ease, we define the representative financial intermediary's income as:

$$Inc_t \equiv div_t + dst_t + gns_t^c + gns_t^n + p_t^r H_t^r - \delta^r H_{t-1}^r + \rho_t B_t^g + i_t B_t^c + i_t B_t^c \tag{2.22}$$

It is assumed that the intermediary does not discount the future, so intertemporal profit can be written as:

$$\Pi_t = \sum_{s=t}^{\infty} Inc_s - (1+r_s^p)D_t - \Delta V_s^c - \Delta V_s^n - \Delta B_s^g - \Delta B_s^c - \Delta B_s^n - \Delta H_{s-1}^r + D_{s+1} \tag{2.23}$$

where $\Delta H^r_{t-1} \equiv H^r_t - H^r_{t-1}$. In each period the intermediary is constrained by:

$$D_{t+1} = V^c_{t+1} + V^n_{t+1} + B^g_{t+1} + B^c_{t+1} + B^n_{t+1} + H^r_t \quad \forall t \tag{2.24}$$

which states that the end-of-period stock of investments plus current rental housing property held by the intermediary must be equal the end-of-period stock of savings deposited by households. The representative financial intermediary has the objective to use deposits to choose an optimal investment allocation on behalf of households, internalizing their aggregate tax consequences. A characteristic of the optimal allocation is that no arbitrage opportunities exist. This no-arbitrage condition implies that the after-tax marginal rate of return from across corporate and non-corporate equity and debt, as well as on rental housing, will be equalized:

$$R^c_t = R^n_t = (1 - \tau^i_t)i_t = (1 - \tau^r_t)p^r_t - \delta^r \tag{2.25}$$

which yields the following rental housing price:

$$p^r_t = \frac{(1 - \tau^i_t)i_t + \delta^r}{(1 - \tau^r_t)} \tag{2.26}$$

where τ^i_t and τ^r_t are the aggregate effective marginal tax rates on interest and rental income.

Perfect competition in the financial market implies a within-period zero-profit condition for the representative intermediary. Setting $\Pi_t = 0$ for $s = t$ in equation (2.23), using the budgeting constraint in equation (2.24) to eliminate, and solving for the return on deposits yields:

$$r^p_t D_t = Inc_t \tag{2.27}$$

which is the total pretax capital income received by households. The pretax portfolio rate of return r^p_t is received by households with positive savings, or charged as the rate of interest for households who borrow, since the intermediary will be indifferent between investing and lending on the margin.

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 a 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, with the conventional specification described in Section 4.

We denote $i^{z,f}_{t,j}$ as the economic wage income for working-age households or the social security income for retired households, and $a^{z,f}_{t,j}$ as the deposits of financial assets held by the financial intermediary of a household so that $r^p_t a^{z,f}_{t,j}$ is the flow of economic capital income, which is composed of the different capital income types indexed by $k \in$ {dividends, distributions, interest, capital gains, rental income}.

To ensure the correct tax base, we use a (z, f) demographic specific 'calibration ratio' to scale particular flow of economic income which may be subject to taxation, with $\chi^{\boldsymbol{i},z,f}$ used for labor income, and $\chi^{\boldsymbol{o},z,f}_k$ used for each particular capital income type, k, that is treated as ordinary. We obtain adjusted gross labor income, $\hat{i}^{z,f}_{t,j}$, and adjusted gross ordinary capital income, $r^p_t \hat{a}^{\boldsymbol{o},z,f}_{t,j}$, as follows:

$$\begin{aligned} \hat{i}^{z,f}_{t,j} &\equiv \chi^{\boldsymbol{i},z,f} i^{z,f}_{t,j} \\ r^p_t \hat{a}^{\boldsymbol{o},z,f}_{t,j} &\equiv r^p_t \left(\sum_k \chi^{\boldsymbol{o},z,f}_k s^{\boldsymbol{o}}_{t,k} \right) a^{z,f}_{t,j} \end{aligned} \tag{2.28}$$

where $s^{\boldsymbol{o},\boldsymbol{k}}_t$ is the share of total portfolio income for ordinary capital income type k. We can then define adjusted gross ordinary income as:

$$ord^{z,f}_{t,j} \equiv \hat{i}^{z,f}_{t,j} + r^p_t \hat{a}^{\boldsymbol{o},z,f}_{t,j} \tag{2.29}$$

The portion of economic capital income not treated as ordinary is instead treated as preferred capital income, $pci^{z,f}_{t,j}$. Adjusted gross preferred capital income is obtained by applying a calibration ratios $\chi^{\boldsymbol{p},z,f}_k$:

$$pci^{z,f}_{t,j} \equiv r^p_t \left(\sum_k \chi^{\boldsymbol{p},z,f}_k s^{\boldsymbol{p}}_{t,k} \right) a^{z,f}_{t,j} \tag{2.30}$$

where $s^{\boldsymbol{p},\boldsymbol{k}}_t$ is the share of total portfolio income for capital income type k is treated as preferential, with the aggregate consistency condition $\Sigma_k \left(s^{\boldsymbol{o}}_{t,k} + s^{\boldsymbol{p}}_{t,k} \right) = 1$. A households' tax liability on preferential capital income depends on their total adjusted gross income and a statutory rate schedule. We define this relationship with the following function:

$$cit^{z,f}_{t,j} = \boldsymbol{q}(ord^{z,f}_{t,j}, pci^{z,f}_{t,j}) \tag{2.31}$$

A given household's net tax income liability $\mathcal{T}^{z,f}_{t,j}$ is equal to taxes owed on ordinary income, $oit^{z,f}_{t,j}$, plus tax liability on preferred capital income, $cit^{z,f}_{t,j}$, plus tax liabilities associated with the Social Security system for retirees, $\tau^{pr}_{t,j} \hat{i}^{z,f}_{t,j}$, less federal transfer payments, $trs^{z,f}_{t,j}$, plus state and local tax liabilities, $slt^{z,f}_{t,j}$.

$$\mathcal{T}^{z,f}_{t,j} = oit^{z,f}_{t,j} + cit^{z,f}_{t,j} + \tau^{pr}_{t,j} \hat{i}^{z,f}_{t,j} - trs^{z,f}_{t,j} + slt^{z,f}_{t,j} \tag{2.32}$$

Household tax liability on ordinary income, $oit^{z,f}_{t,j}$, 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 effective marginal tax rate is therefore not the statutory tax rate, but the marginal liability on incremental labor income after these deductions and credits have been applied.

The average tax rate on ordinary income before tax credits, τ^o_t, is determined by the statutory tax rate schedule in the tax calculator, ordinary income $ord^{z,f}_{t,j}$, and deductions $ded^{z,f}_{t,j}$. Deductions vary, as some are a function of labor income only, others consider broader income sources, and some are a function of tax-preferred consumption choices made by the household. All variables affecting possible deductions are listed in equation 2.35. Due to the refundability of some credits, $crd^{z,f}_{t,j}$ is a function of various income definitions, deductions themselves, and also child care costs, $\kappa^{z,f}_{t,j}$. Formally, ordinary income tax liability is given by:

$$oit_{t,j}^{z,f} = \max\left\{\tau_t^o ord_{t,j}^{z,f}, 0\right\} - crd_{t,j}^{z,f} - tra_t^{z,f} \tag{2.33}$$

$$\tau_t^o = \boldsymbol{\tau}(ord_{t,j}^{z,f} - ded_{t,j}^{z,f}) \tag{2.34}$$

$$ded_{t,j}^{z,f} = \boldsymbol{d}(\hat{i}_{t,j}^{z,f}, ord_{t,j}^{z,f}, pci_{t,j}^{z,f}, h_{t,j}^o, c_{t,j}^g) \tag{2.35}$$

$$crd_{t,j}^{z,f} = \boldsymbol{c}(\hat{i}_{t,j}^{z,f}, ord_{t,j}^{z,f}, ded_{t,j}^{z,f}, pci_{t,j}^{z,f}, \kappa_{t,j}^{z,f}) \tag{2.36}$$

$$tra_t^{z,f} = \begin{cases} \boldsymbol{a}(\hat{i}_{t,j}^{z,f}) & \text{if } n_j > 0 \text{ and } f = s \\ \boldsymbol{a}(\hat{i}_{t,j}^{z,f}) & \text{if } n_j^1 > 0 \text{ and } f = m \\ 0 & \text{otherwise} \end{cases} \tag{2.37}$$

where bold emphasis denotes a function. The last term in equation (2.33), is a productivity type - family composition specific transfer payment $tra_t^{z,f}$, which is used as a non-distortionary method of ensuring that households within a given (z, f) 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 only nonzero for working households.

Preferred capital income sources are taxed at various rates, with a progressive schedule in the case of gains and dividends. This mapping, like that for ordinary income tax liabilities, is developed to be as close to the actual IRC as possible. Under this tax system, households consider the tax implications of their realized capital income when making their joint labor supply and savings decisions.

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:

$$\tau_{t,j}^{pr} = \boldsymbol{p}\left(\hat{i}_{t,j}^{z,f}\right) \text{if} \quad j \leq R \tag{2.38}$$

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

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, from corporations, and on accidental bequests, respectively. 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:

$$I_t^{fed} + C_t^{fed} + TR_t^{fed} \leq T_t^{fed} + B_{t+1}^g - (1 + \rho_t)B_t^g \tag{2.39}$$

where the law of motion for federal public capital follows:

$$G_{t+1}^{fed} = (1 - \delta^g)G_t^{fed} + I_t^{fed} \tag{2.40}$$

Equation (2.39) 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, $B^g_{t+1} - B^g_t$, less interest paid on old debt $\rho_t B^g_t$. To rule out explosive debt paths, we maintain the no-Ponzi condition:

$$\lim_{k\to\infty} \frac{B^g_{t+k}}{\prod_{s=0}^{k-1}(1+\rho_{t+s})} = 0 \tag{2.41}$$

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^{hh}_t consist of tax liabilities from both ordinary and preferred income, which include distributions from non-corporate business entities, as well as payroll taxes and tax liabilities on social security income:

$$txl^{hh}_t = \int_{\mathbb{Z}}\int_{\mathbb{J}} \sum_{f=s,m} \left(oit^{z,f}_{t,j} + cit^{z,f}_{t,j} + \tau^{pr}_t \hat{\imath}^{z,f}_{t,j} \right) \Omega^{z,f}_{t,j} \; dj \; dz \tag{2.42}$$

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

$$txl^c_t = \tau^c_t \left(Y^c_t - w_t N^c_t - ded^c_t\right) - crd^c_t$$

Taxes are collected on accidental bequests left by deceased households. We specify that the tax rate τ^{beq}_t is linear in bequests 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 $h^o_{t+1,j+1}$, taxes collected on accidental bequests can be expressed as:

$$txl^{beq}_t = \tau^{beq}_t (1-\Lambda) \int_{\mathbb{Z}}\int_{\mathbb{J}} (1-\pi_j) \sum_{f=s,m} y_{t+1,j+1} \Omega^{z,f}_{t,j} \; dj \; dz \tag{2.43}$$

where Λ is a parameter that accounts for end-of-life consumption expenditures by the newly deceased.

In addition to social security payments to retirees, $ss^{z,f}_{t,j}$, households receive transfer payments from the federal government $trs^{z,f}_{t,j} \equiv trl_t + lst_t + trw^{z,f}_{t,j}$ where, as specified in Moore and Pecoraro (2018b), is the sum of lump-sum transfers, lump-sum taxes, and conditional welfare transfers respectively. Aggregate federal government transfers therefore can be expressed as:

$$TR^{fed}_t = \int_{\mathbb{Z}}\int_{\mathbb{J}} \sum_{f=s,m} \left(ss^{z,f}_{t,j} + trs^{z,f}_{t,j} \right) \Omega^{z,f}_{t,j} \; dj \; dz \tag{2.44}$$

2.4.3 State and Local Government

Total taxes collected by the composite state and local government T^{sl}_t 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^{sl}_t and investment in productive public capital I^{sl}_t. We specify an intraperiod balanced-budget constraint such that:

$$I^{sl}_t + C^{sl}_t = T^{sl}_t \tag{2.45}$$

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

$$G_{t+1}^{sl} = (1-\delta^g)G_t^{sl} + I_t^{sl} \tag{2.46}$$

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

$$slt_{t,j}^{z,f} \equiv \tau_t^{sl}\hat{i}_{t,j}^{z,f} + \tau_t^{slp}h_{t,j}^{o} \tag{2.47}$$

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:

$$T_t^{sl} = \int_{\mathbb{Z}}\int_{\mathbb{J}}\sum_{f=s,m} slt_{t,j}^{z,f}\Omega_{t,j}^{z,f}\ dj\ dz + slt_t^c \tag{2.48}$$

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 Baseline 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 Taxations' Individual Tax Model (ITM) for specification, which makes use of data from individual tax returns filed with the Internal Revenue Service (IRS) and compiled by the IRS Statistics of Income (SOI) Division.[5] 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. In using 2017 as the initial year, we ensure that the projected effects of Public Law 115-97 are not incorporated our initial baseline.

[5] For a description of the Joint Committee on Taxation's Individual Tax Model, see JCT (2015)

3.1 Non-Tax Policy Parameters and Targets

The calibration strategy for household demographics, characteristics, and preference generally follows that described in Appendix A of Moore and Pecoraro (2018b); any deviations from the prior calibration strategy are described in Section A.1.1. Select exogenous parameters used are summarized in Table A1, with key aggregate targets for labor supply, business capital accumulation, and housing capital accumulation are summarized in Tables A2 and A3. The calibration strategy for the production sector and non-tax portion of government in our economy is described Sections A.1.2 and A.1.3.

3.2 Tax Policy Parameters and Targets

The set of aggregate effective marginal tax rates, which apply to aggregate corporate income, non-corporate income, pass-through income, dividend income, interest income, and capital gains are exogenously set to those values computed by the ITM for year 2017. In addition to wage expense, both the corporate and non-corporate firms are able to deduct from taxable income their interest expense, depreciation of capital assets, and state and local tax liabilities in the initial baseline. So that corporate and non-corporate tax liabilities relative to output each match an empirical counterpart for 2017, we endogenously calibrate a lump-sum credit. For the corporate firm we target the tax liability to output ratio estimated by the Congressional Budget Office (CBO) in the *The Budget and Economic Outlook: 2017 to 2027* for 2017, and for the non-corporate firm we target that ratio estimated by the ITM for 2017.

The internal tax calculator, specified in Section 2.4.1 explicitly models the following individual tax provisions in the Internal Revenue Code of 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 internal tax calculator produces household capital income tax liabilities to output ratios that are consistent with those estimated by the ITM for each capital income type for 2017, we endogenously compute values for the calibration ratios $\chi_k^{\boldsymbol{o},z,f}$ and $\chi_k^{\boldsymbol{p},z,f}$ over the k dimension.[6] These values are exogenously scaled over the z dimension to match the relative values of taxable capital income estimated by the ITM for the average household of each productivity demographic.

The share total portfolio income attributed to each capital income type k to be treated as ordinary, $s_{t,k}^{\boldsymbol{o}}$, or preferential, $s_{t,k}^{\boldsymbol{p}}$, 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 $\bar{\mu}_{t,k}^{o}$ denote the exogenous share of a given capital income type k that is treated as ordinary for tax purposes, which is estimated by the ITM for 2017. The portfolio shares for each k can then be obtained as follows:

$$s_{t,k}^{\boldsymbol{o}} = \bar{\mu}_{t,k}^{o}\mu_{t,k}$$
$$s_{t,k}^{\boldsymbol{p}} = (1 - \bar{\mu}_{t,k}^{o})\mu_{t,k}$$

[6] Note that this procedure ensures that the aggregate tax liabilities internalized by the non-corporate firm at the business-entity level match those remitted to the government by households.

where by construction the aggregate consistency condition $\Sigma_k \left(s^{\boldsymbol{o}}_{t,k} + s^{\boldsymbol{p}}_{t,k}\right) = 1$ holds.

The calibration ratio for labor income $\chi^{\boldsymbol{i},z,f}$ is computed as the ratio of wages in adjusted gross income to a NIPA-comparable wage income concept for each (z, f) demographic as computed by the ITM.[7] To ensure that the average federal income tax rates for the average household in each (z, f) demographic in the model match those computed by the ITM, we set $tra^{z,f}$ endogenously in the initial steady state as described in Section 3.1.1 of Moore and Pecoraro (2018b). As in the previous work, the OASDI portion payroll tax rate of 12.4% applies to labor income up to the 2017 tax-law threshold. The OASDI-taxable income base is adjusted uniformly across taxpayers so that payroll tax receipts relative to output are about 4.4% as estimated by CBO for 2017.

Specification of the federal transfer payments $trs^{z,f}_j$, the linear tax rate on bequests τ^{beq}, and the linear state and local tax rate τ^{sl} follow from Section 3.1 of Moore and Pecoraro (2018b), using year 2017 targets instead of those from 2018 for the initial steady state baseline. 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 endogenously 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 Conventional Household-level Tax Specification

This section describes a conventional tax specification (CTS) for household-level income tax treatment, used for purposes of comparison to the internal tax calculator. We specify this tax system to exhibit three characteristics common to macroeconomic models of tax policy: (*i*) smooth and continuous tax functions used to determine tax liabilities on household income; (*ii*) labor and capital income treated as separate tax bases; (*iii*) capital income taxed in composite form, without distinction between income from business, interest, dividend, or capital gains for purposes of preferential tax treatment.

As in Moore and Pecoraro (2018b), for the taxation of labor income 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:

$$wit^{z,f}_{t,j} = \hat{i}^{z,f}_{t,j} - \lambda^f_1 (\hat{i}^{z,f}_{t,j})^{1-\lambda^f_2} \tag{4.1}$$

where λ^f_1 and λ^f_2 are parameters which together determine the income-weighted average tax rate and effective marginal tax rate applied to labor income at for each family composition.

Average tax rates on capital income are determined the by age group - family composition specific tax functions used in Moore and Pecoraro (2018b), where a unique function estimated each for working single, working married, retired single, and retired

[7] See Section A.1.1 for a description of the NIPA-comparable wage income concept.

married household. We assume that a household's average tax rate on capital income is a monotonically increasing function of their asset holdings relative to the asset distribution $\boldsymbol{f}(a_t|f,j)$, conditional on family composition and age.[8] These functions allow households' tax liability on capital income, which may vary significantly over their lifecycle, to be independent of their permanent productivity type. We assume that this function takes a quadratic form:

$$\tau_t^a = q_{0j}^f + q_{1j}^f(a_{t,j}^{z,f}) + q_{2j}^f(a_{t,j}^{z,f})^2 \tag{4.2}$$

While payroll taxes are levied in the same manner as specified in equation (2.38), the special tax treatment of the Security Security income received by retired households is captured using (z,f) demographic specific exogenous average tax rates applied that income. We denote the tax rates associated with the retirement system as $\tau_{t,j}^{pr}$

$$\tau_{t,j}^{pr} = \begin{cases} \boldsymbol{p}\left(\hat{i}_{t,j}^{z,f}\right) & \text{if} \quad j \leq R \\ \boldsymbol{r}\left(ss_{t,j}^{z,f}\right) & \text{if} \quad j > R \end{cases} \tag{4.3}$$

Under this alternative tax system, total household tax liabilities are given by the following:

$$\mathcal{T}_{t,j}^{z,f} = wit_{t,j}^{z,f} + \tau_t^a \tilde{a}_{t,j}^{z,f} r_t^p + \tau_{t,j}^{pr}\hat{i}_{t,j}^{z,f} - tra_t^{z,f} - trs_{t,j}^{z,f} + slt_{t,j}^{z,f} \tag{4.4}$$

where $trs_{t,j}^{z,f}$ are as specified as in Section 2.4.2 and $slt_{t,j}^{z,f}$ is as specified in equation (2.47). The transfers $tra_t^{z,f}$ are used as a non-distortionary method of targeting changes to the average tax rate on labor income for (z,f) demographic group following a policy change.

For initial steady state calibration of the Bénabou tax function, capital income tax function, and retirement tax framework, we follow that strategy described in Section 3.1.1 and 4.1 of Moore and Pecoraro (2018b) while choosing 2017 as the initial year over 2018.

5 Policy Experiments

We analyze the transition path following implementation of two different subsets of tax changes contained in the recently enacted "Tax Cuts and Jobs Act": (*i*) the individual tax provisions; and (*ii*) the corporate rate reduction. These experiments are performed using the internal tax calculator (ITC) as described in Section 2.4.1 and conventional tax specification (CTS) as described in Section 4, each in turn, beginning from an initial steady state associated with 2017 tax law. TCJA provisions are considered separately to focus on two different model features: (*i*) the tax detail for ordinary income in the case individual tax changes and (*ii*) distinctions of various capital income types, and the joint taxation of labor and ordinary capital income in the case of the corporate rate reduction.

In comparing the ITC and the CTS tax systems, we first look at deviations in household-level choices and then connect these deviations to their macroeconomic consequences. We report aggregate variables over 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.

[8] Since all households face the same rate of return on deposits and calibration ratios applied to capital income, an ordering of households by capital assets is equivalent to an ordering of households by taxable capital income.

As in Moore and Pecoraro (2018b), the announcement and implementation of a new tax policy occurs in 'year 1', and is assumed to be unanticipated in the 'year 0' initial steady state. Following the policy change, agents in the model 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 the Federal budget is on a sustainable debt path in the long-run as the economy reaches a final steady state, adjustments to non-valued government consumption expenditures and lump-sum transfers are phased in over years 31 through 40.[9]

5.1 Calibrating Tax Instruments for Policy Changes

Both the ITC and the 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'.[10] For each tax system, tax instruments are adjusted to target the total conventional 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 and aggregate level are made identically under both the ITC and the CTS. Specifically, we change the aggregate marginal tax rates on corporate income, non-corporate 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, 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.

5.1.1 Internal Tax Calculator

Changes to the taxation of household income under the ITC are explicitly incorporated in the tax calculator as specified by 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 $tra_t^{z,f}$ to target the distribution of the conventional revenue effect across (z, f) demographics as predicted by the ITM over the budget window. Second, we adjust the calibration ratios for both ordinary and preferential capital income, $\chi_k^{\boldsymbol{o},z,f}$ and $\chi_k^{\boldsymbol{p},z,f}$, 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 decomposed across demographics and type of income.

[9] Delayed adjustment of fiscal instruments to maintain fiscal sustainability minimizes the within-budget-window noise introduced by the specific 'fiscal closure' rule chosen. See Moore and Pecoraro (2018a) for a discussion.

[10] 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.

5.1.2 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 those changes due to the proposal as predicted by the 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 $tra_t^{z,f}$, set to zero in the initial baseline under the CTS, are set to target the distribution of the conventional revenue effect across (z, f) demographics as predicted by the ITM. Changes to the taxation of household capital income are made by re-estimating equation (4.2) using the average tax rates on capital income under the proposal as predicted by the ITM for each (f, j) demographic over the budget window. We scale the total change in average tax rates to match the portion of the total conventional revenue effect due to capital income changes.

5.2 Policy Experiment 1: Individual Tax Provisions of TCJA

We simulate the enactment of the individual tax provisions as reported in Title I of JCT (2017), most of which became effective beginning in 2018 and are scheduled to sunset in 2025. Key among these provisions, all of which are modeled explicitly with the tax calculator, are changes to the statutory rate schedule 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 the individual 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.

5.2.1 Household Behavior

The decrease in statutory tax rates on ordinary income combined with the near doubling of the standard deduction drive differences in micro-level behavior across tax systems. While the statutory rate reduction decreases effective marginal and average tax rates on ordinary income for those households who had taxable income prior to the policy change, the larger standard deduction expands the effective "zero bracket" for households without taxable income and reduces the tax base for households with taxable income. The lowest productivity households who typically earn annual labor income around or below the expanded standard deduction amount in the initial baseline, increase average labor hours over 2018-2025[11] by 0.6% for singles and 2.1% for married households relative to baseline under the ITC; these groups decrease hours by -0.6% and -1.2% relative to baseline under the CTS. The remainder of single and married households — middle- to high-productivity types — change average hours by -0.1% and 1.5% respectively under the ITC, and by 0.1% and 2.1% under the CTS over the same period. The relatively smaller labor supply response of high-productivity workers under the ITC is due to the joint taxation of labor and ordinary capital income, a feature of this tax environment which can also dampen the savings response when labor income is increasing.

The expansion of the standard deduction reduces the number of households who itemize deductions, and the reduction in the statutory tax rates reduces the value of

[11] We focus on this subset of the budget window as the temporary provisions sunset beginning in 2026.

itemized deductions for those still itemizing. Together, these policy changes most directly affect the tax-preferred consumption behavior of high-income households who are more likely to itemize deductions for home mortgage interest and charitable giving. Following the policy change, these households face incentives to purchase relatively smaller homes, or remain in a rental unit longer before buying a home, and to reduce charitable giving. Figure 1 displays the aggregate quantities of these tax-preferred consumption choices over time under both tax systems, showing that the explicit modeling of these provisions under the ITC captures the new disincentives. Under the ITC, households have a 0.9 percentage point lower stock of owner-occupied housing than under the CTS on average each year over 2018-2025. Similarly, charitable giving is 4.6 percentage points lower under the ITC on average over the same period.

5.2.2 Aggregate Effects

The paths of aggregate variables following the implementation of TCJA individual tax provisions are shown in Figure 2. While effective (productivity-weighted) labor supply increases by 1.5% on average each year over 2018-2025 relative to baseline under both tax systems, labor hours increase more under the ITC environment on average reflecting the larger increase in hours of low productivity workers. The accumulation of financial deposits is 0.3 percentage points lower on average each year over the first half the decade under the ITC, reflecting the savings disincentives from joint taxation of labor and ordinary capital income. As the difference in the stock of financial deposits across tax systems shrinks towards the middle of the budget window, so does difference in the flow of market consumption — from 0.6 percentage points in 2018 to 0.1 percentage points in 2022 — which is additionally bolstered by substitution away from tax-preferred consumption choices under the ITC.

The relatively slower accumulation of financial deposits under the ITC facilitates a relatively higher borrowing rate for firms, thereby slowing the accumulation of physical capital. While the stock of capital is 0.1 percentage points lower over average over 2018-2015 under the ITC, the average annual difference in aggregate output across tax systems in negligible over this period. Nonetheless, the combination of a lower stock of deposits and relatively higher concentration of low-productivity labor in the first half of the budget window leads to a larger federal tax revenue loss under the ITC by 0.4 percentage points. Lower tax revenues result in a higher level of public debt than that predicted under the CTS by 0.6 percentage points by the end of 2027.

Figure 3 decomposes the change to federal tax revenues across the returns to labor and capital, omitting the tax revenues from accidental bequests. While the cumulative total of (taxable and non-taxable) labor income over the budget window is about \$80 billion higher under the ITC, the cumulative total of labor income taxes is about \$60 billion lower. The inverse directions of income and taxes is due to the relative concentration of low-productivity household labor increases, who generally face lower effective tax rates on ordinary income. The cumulative totals of (taxable and non-taxable) capital income and capital income taxes are approximately \$305 billion and \$37 billion higher under the ITC, as the recipients of taxable capital income generally face higher effective tax rates under this tax system. Considering together that the labor and capital income tax receipts go in opposite directions, the net difference in total tax receipts across tax systems is only \$23 billion. Thus, the net difference masks substantial variation in changes to the distribution of pre- and post-tax returns to labor and capital.

5.3 Policy Experiment 2: TCJA Corporate Tax Rate Reduction

We simulate the enactment of the corporate rate reduction as in Title II of JCT (2017), which became effective beginning in calendar year 2018. The reduction in the statutory rate on corporate income from previous law to a single 21% rate was estimated to have a conventional revenue loss of $1.349 trillion over fiscal years 2018-2027 in JCT (2017), which is matched under both the ITC and CTS tax systems.

We simulate the enactment of the corporate rate reduction as in Title II of JCT (2017), which became effective beginning in calendar year 2018. The reduction in the statutory rate on corporate income from previous law to a single 21% rate was estimated to have a conventional revenue loss of $1.349 trillion over fiscal years 2018-2027 in JCT (2017), which is matched under both the ITC and CTS tax systems.

5.3.1 Household Behavior

The reduction in the marginal tax rate applied to corporate income results in physical capital moving from the non-corporate to the corporate sector, with a subsequent increase in corporate dividend payments and capital gains realizations, and a decrease in non-corporate distributions, in households' reallocated portfolios. This increase in preferred capital income and reduction in ordinary capital income is associated with an implicit reduction in the effective tax rate applied to all ordinary income, which includes labor income when taxed jointly as under the ITC. High productivity households, who are generally those with large quantities of taxable capital income, will then experience a greater effective tax rate reduction and an incentive to increase labor hours and savings.

Under the ITC, the highest two productivity single and married households increase average annual labor hours by 0.2% and 0.3% relative to baseline over 2018-2027. This contrasts with the CTS, where capital income taxation is independent of labor income taxation, as these households exhibit approximately no change in labor hours. With lower effective tax rates under the ITC, these high productivity single and married households respond to the savings incentive by increasing their stock of financial deposits by a budget-window annual average of 0.2 and 0.4 percentage points more than under the CTS. The policy-induced savings behavior of these households account for the largest change to the stock of deposits and flow of capital income under both tax systems.

For households with little taxable capital income, the strength of the labor supply incentives created by the portfolio re-balancing effect is negligible. The labor response along the substitution margin is primarily driven by changes to the pre-tax wage rate for these households, which increases by 0.1 percentage points less under the ITC due to the greater change in the labor supply of high-productivity workers. Consequentially, we observe the lowest three productivity single and married households to have higher average annual labor hours under the CTS by 1.2 and 0.1 percentage points over the budget window. Nonetheless, these relatively low productivity households tend to reduce labor hours towards the end of their working life in response to the income effect of a higher wage rate and rate of return to financial deposits.

5.3.2 Aggregate Effects

The paths of aggregate variables following the implementation of the TCJA corporate rate reduction are shown in Figure 4. While effective labor supply increases under both tax systems, it is higher under the ITC by an annual average of 0.2 percentage points over 2018-2027. In spite of this, labor hours are about 0.2 percentage points lower under the ITC on average over this period. This result reflects the portfolio re-balancing effect, which generates an increase in labor supply by high productivity households under the ITC. With a similar capital accumulation response across tax systems, this differential in effective labor supply causes a differential in aggregate output of about 0.2 percentage points over the budget window. Higher output under the ITC is associated with relatively smaller tax revenue loss, resulting in a stock of public debt that is 1.0 percentage points lower at the end of the budget window.

The total difference in the federal tax revenue loss over the budget window under the ITC is approximately \$119 billion smaller than under the CTS, omitting the taxation of accidental bequests. Figure 5 decomposes this substantial difference across the total (taxable and non-taxable) returns to labor and capital. The ten-year cumulative flows of labor and capital income are higher under the ITC by \$224 billion and \$332 billion, which reflect the relative sensitive labor supply and savings responses of high productivity households to this particular policy change under the ITC. As these high-income households are subject to relatively higher effective tax rates under a progressive tax system, these changes are associated with about \$50 billion and \$69 billion more in labor and capital income taxes collected after ten years under the ITC.

6 Conclusion

Macroeconomic analysis of large tax legislation packages often involves two stages: First, a microsimulation outside of the macroeconomic model is used to calculate tax changes for households and compute a change to effective marginal and average aggregate tax rates for each source of income. Second, these changes are then used to calibrate tax functions that are imposed exogenously onto agents within the model. In this paper, we combine these stages by embedding an internal tax calculator within a heterogeneous-agent model so that decision makers within the model internalize the effect that their particular choices and demographics have on their tax liability under the policy change. The innovation of this approach is that the tax treatment of preferred and ordinary capital income flows, which are taxed separately and explicitly according to their respective statutory rate schedules rather than as a single tax base. Ordinary capital income is then taxed jointly with labor income while explicitly accounting for endogenous values of deductions and credits that may cause deviations from effective and statutory rates.

We have explored the extent to which these modeling choices matter for an analysis of two subsets of tax provisions in Public Law 115-97, known as the "Tax Cuts and Jobs Act': i) the individual provisions, and ii) the corporate tax rate reduction. We find that our internal tax calculator approach captures incentives created by the tax changes not captured by the conventional approach. In each case, the care taken in explicitly modeling tax provisions under the internal tax calculator has meaningful quantitative implications both at the microeconomic and macroeconomic level. Our findings imply that abstracting from tax detail in heterogeneous-agent models may come at the expense of completely accounting for household incentives, and therefore the ability reliably estimate macroeconomic responses — especially the resulting tax consequences of changes to the returns to labor and capital — to policy changes.

7 Figures

7.1 Individual TCJA Provisions

Figure 1: Changes to Tax-Preferred Consumption: Individual TCJA Provisions

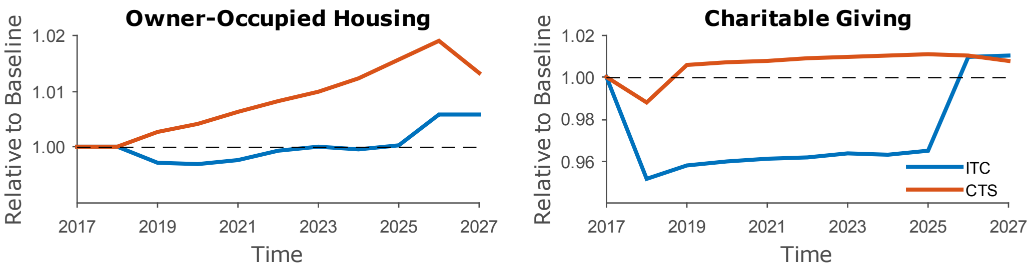


Figure 2: Changes to Aggregates: Individual TCJA Provisions

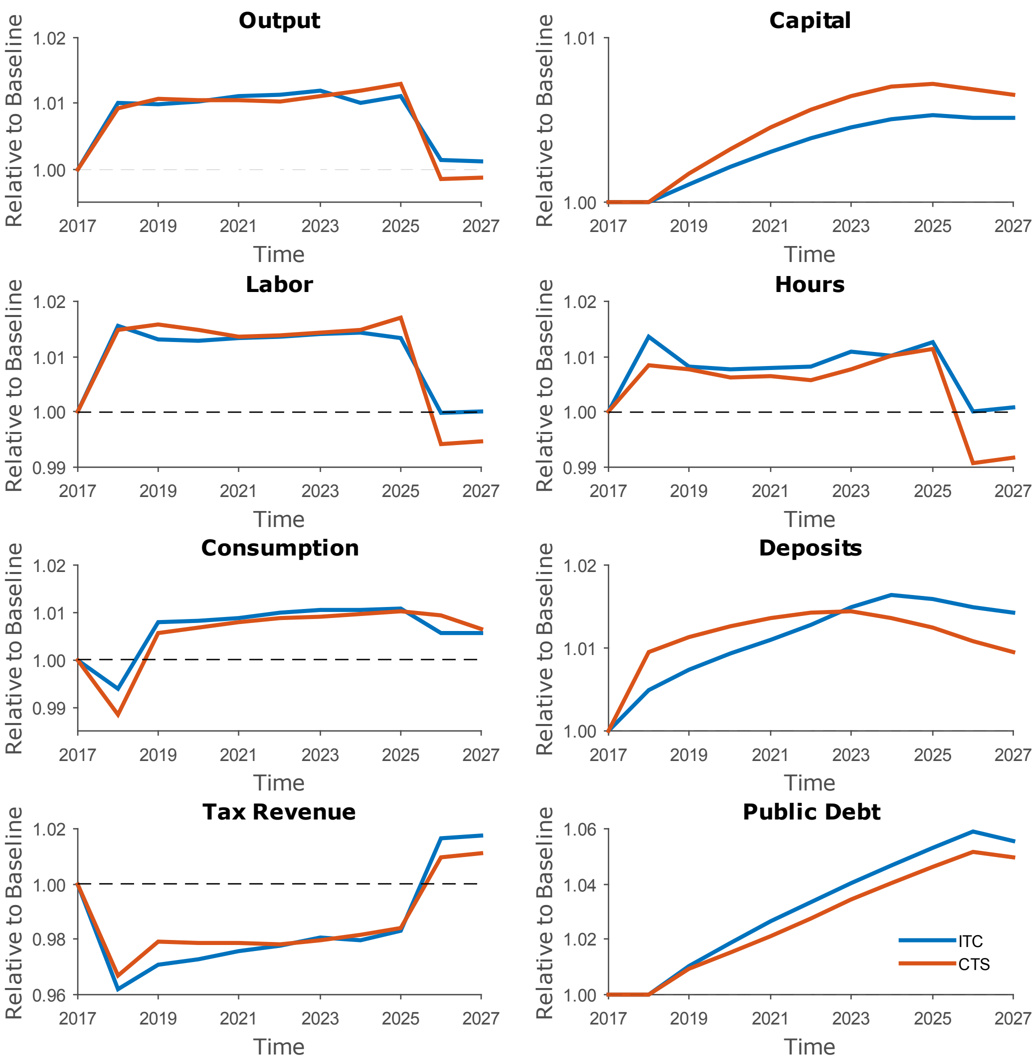
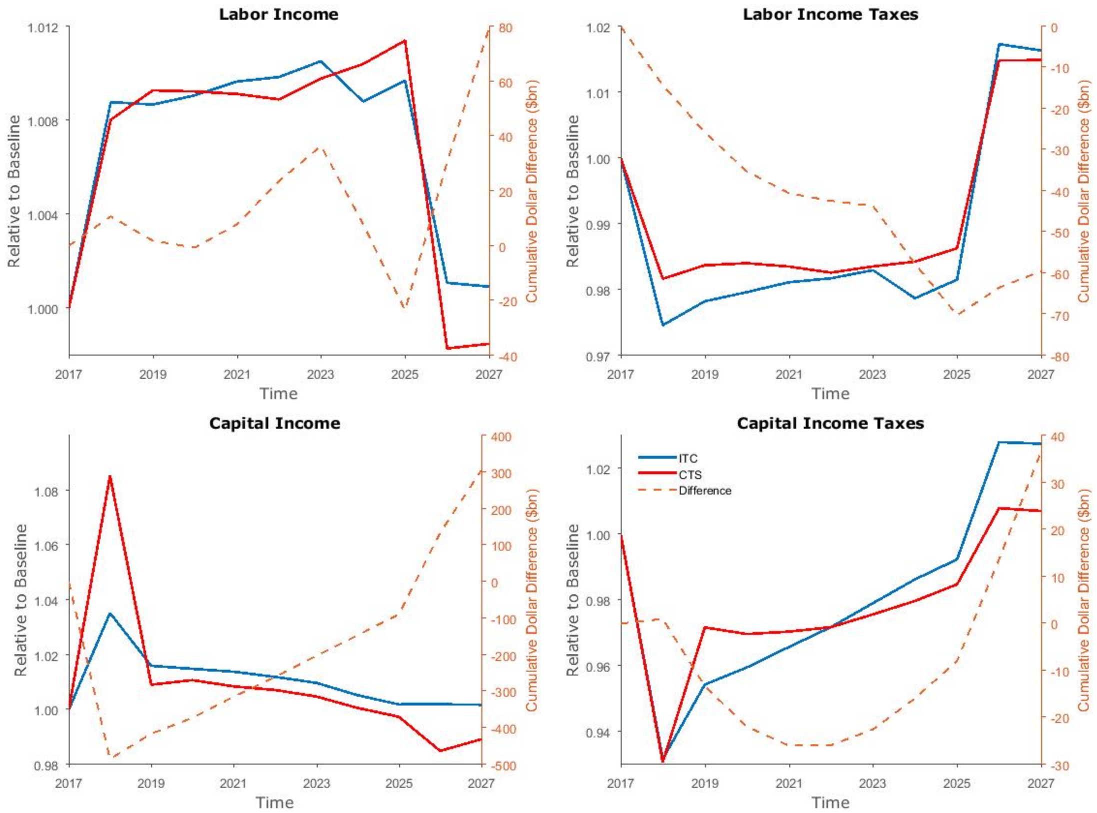


Figure 3: Changes to Factor Returns and Taxes: Individual TCJA Provisions



Labor Income: wage income and social security benefits
Taxes: federal income taxes attributable to labor and social security benefits; payroll taxes
Capital Income: pass-through distributions; corporate dividends; interest; capital gains; corporate profits
Taxes: federal income taxes attributable to the above sources

7.2 TCJA Corporate Rate Reduction

Figure 4: Changes to Aggregates: TCJA Corporate Rate Reduction

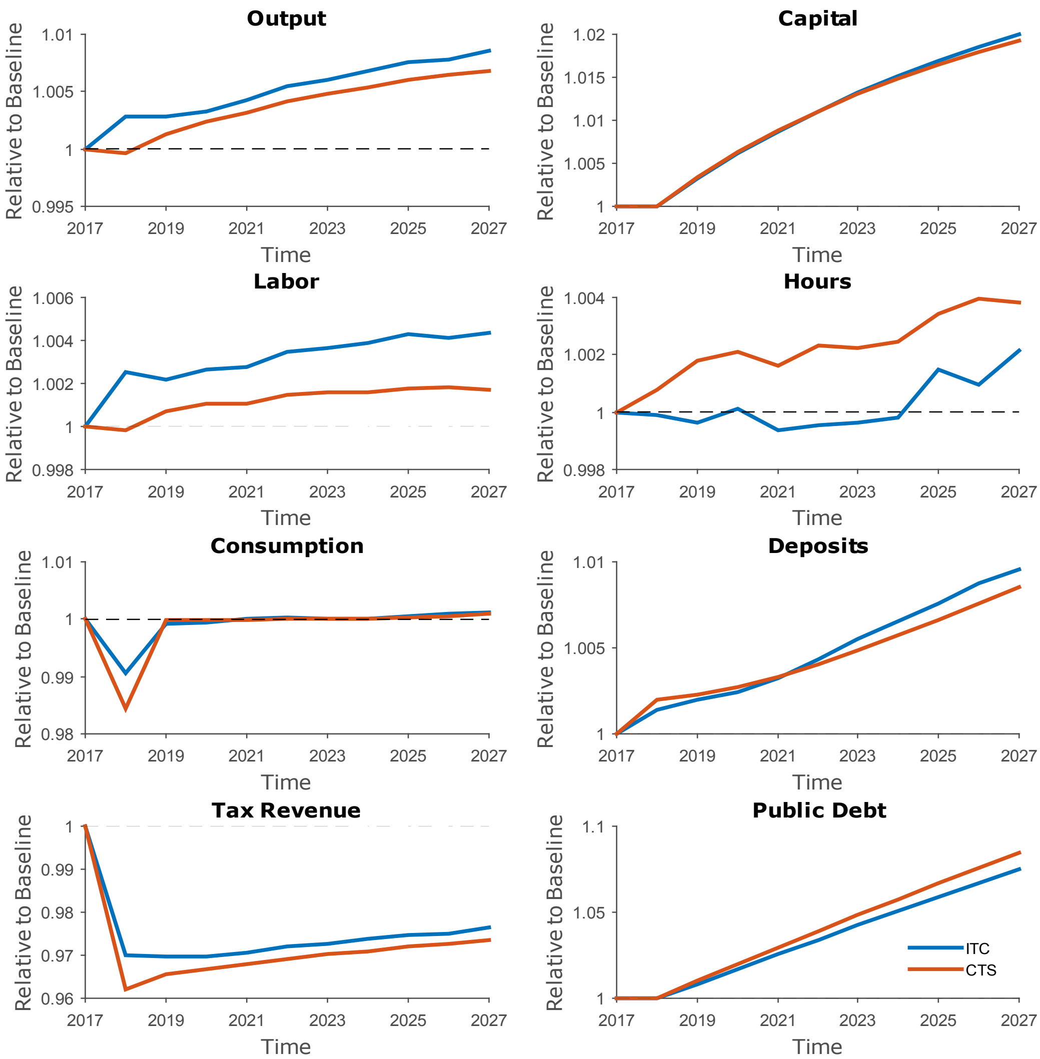
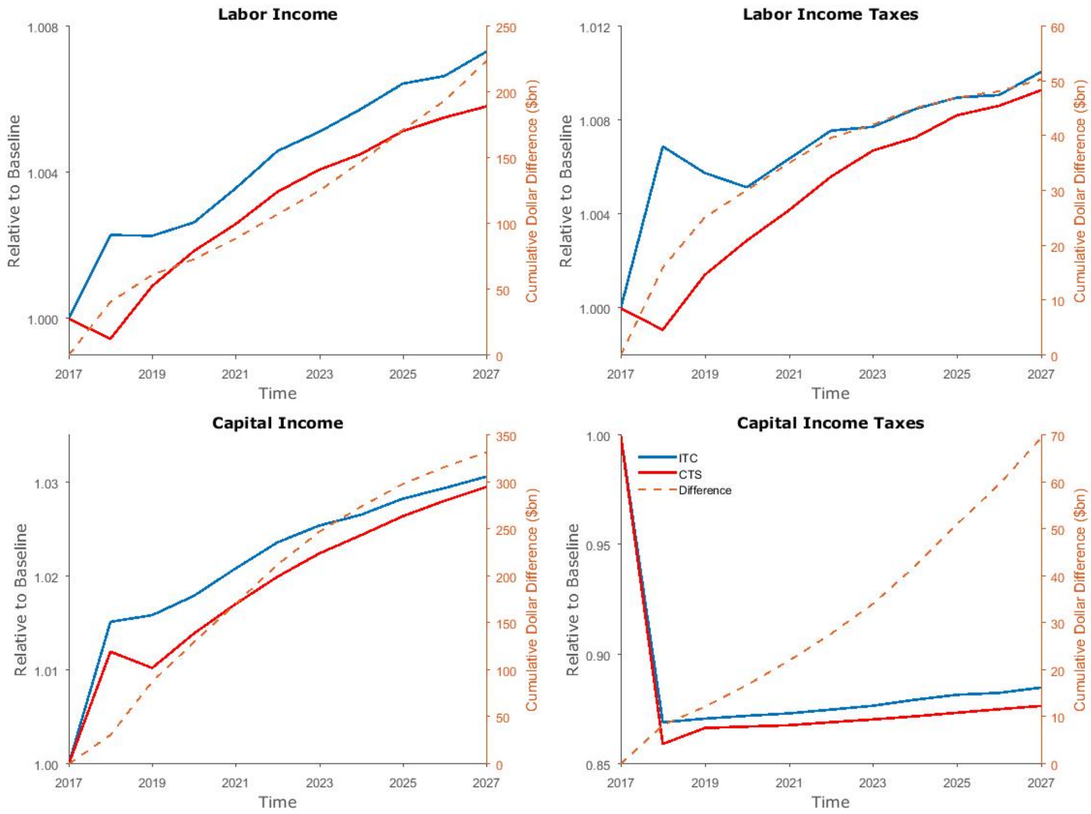


Figure 5: Changes to Factor Returns and Taxes: TCJA Corporate Rate Reduction



Labor Income: wage income and social security benefits
Taxes: federal income taxes attributable to labor and social security benefits; payroll taxes
Capital Income: pass-through distributions; corporate dividends; interest; capital gains; corporate profits
Taxes: federal income taxes attributable to the above sources

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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 (2018b), the calibration strategy for household demographics, preferences, characteristics generally follows that described in Sections A.1.1, A.1.3, and A.2 of that paper. 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 (2018b) 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 previously reported. Only two deviations from the prior calibration strategy for the household sector are made in this paper, which are described below.

The instantaneous utility function is altered from Moore and Pecoraro (2018b) to account the effect of children at home on the supply of market labor hours. In the spirit of Guner et al. (2011), we specify the following utility function:

$$U_{t,j}^{z,f} \equiv \begin{cases} \log(x_j^*) - \psi^s \frac{(n_j + \varphi^s \nu_j^{z,f})^{1+\zeta^s}}{1+\zeta^s} - F^s & \text{if } f = s \\ \\ \log(x_j^*) - \psi^{m,1} \frac{(n_j^1)^{1+\zeta^{m,1}}}{1+\zeta^{m,1}} - \psi^{m,2} \frac{(n_j^2 + \varphi^m \nu_j^{z,m})^{1+\zeta^{m,2}}}{1+\zeta^{m,2}} - F^m & \text{if } f = m \end{cases}$$

where the additive product along with labor hour in the disutility for labor function, $\varphi^f \nu_j^{z,f}$, captures the interaction between lifecycle disutility of work and the presence of children. We let $\nu_j^{z,f}$ be the number of dependents under the age of 6 for a given (j, z, f) demographic, which are calculated using the Joint Committee on Taxations' Individual Tax Model (ITM) for 2017.[2] The parameter φ^f is set equal to 0.094 so that parents spend about 520 hours per children each year, (Hotz and Miller, 1988), which is broadly consistent with the time value specified by Guner et al. (2011).

We define labor income to be equal to the NIPA-comparable wage concept used Moore and Pecoraro (2018b).[3] That is, we do not include a share of pass-through income in our labor income definition for purposes of sorting households by labor income productivity as previously specified. Relative to the implicit composite income concept, we can better account for the joint tax treatment of pass-through and wage income because the expanded production sector in this model allows for the explicit decomposition of capital income across different types.

[1] Parameters calibrated to the single year 2018 in Moore and Pecoraro (2018b) 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.*

[2] For a description of the Joint Committee on Taxation's Individual Tax Model, see JCT (2015)

[3] Our 'NIPA-comparable' measure is computed using the 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.

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 (2018b), 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 Section A.1.2 of that paper. Those parameter values are reported in Table A1 below. The strategy for calibrating the additional parameter values used in our current two-sector framework are described below, and summarized in Table A3 .

Both the corporate and non-corporate firms are assumed to finance operations with some combination of debt and equity such that each representative firm maintains a constant debt to physical 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 non-corporate 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 non-corporate firm are computed as a residual from the non-corporate 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 not corporate entities, 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 productive public capital is set endogenously so that in the initial steady state we observe ratios of federal and state-local public capital to output of 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 deviation of the deficit to output ratio from the corresponding steady state value. The parameter ϖ determines the steady state rate of interest on public debt, and is set so that 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%. The parameter ς determines the response of the interest rate to changes in the deficit to output ratio, and is set equal to 0.0198, which implies that the interest rate increases by 2 basis points for every 1 percent increase in the deficit to output ratio above the steady state value, and vice versa (Gamber and Seliski, 2019; Huntley, 2014).

A.2 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^o, ϕ^r	0.05, 0.05
Housing services depreciation rate	δ^o, δ^r	0.0555, 0.0570
Owner-occupied housing minimum (ITC)	$\underline{\mathrm{h}}^o$	1.00
Owner-occupied housing minimum(CTS)	$\underline{\mathrm{h}}^o$	0.96
Preferences		
Subjective discount factor	β	0.985
Non-housing consumption share of composite	σ	0.295
Housing/non-housing consumption substitution elasticity	η	0.487
Utility curvature parameter	$\zeta^{f,\epsilon}$	5
Intensive labor margin disutility (ITC)	ψ^s,$\psi^{m,1}$,$\psi^{m,2}$	$393.0, 305.1, 89.7$
Intensive labor margin disutility (CTS)	ψ^s,$\psi^{m,1}$,$\psi^{m,2}$	$405.6, 309.0, 102.0$
Extensive labor margin fixed cost (ITC)	ϕ^s, ϕ^m	$0.430, 0.214$
Extensive labor margin fixed cost (CTS)	ϕ^s, ϕ^m	$0.505, 0.203$
Children disutility parameter	φ^f	0.094
Government		
Public capital depreciation rate	δ^g	0.0317
Debt - interest rate response	ς	0.0198

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

Type of Worker	**Data** (MEPS)			**Model: ITC**			**Model: CTS**		
	FT	**PT**	**U**	**FT**	**PT**	**U**	**FT**	**PT**	**U**
Single	0.61	0.24	0.15	0.61	0.24	0.15	0.61	0.24	0.15
Married Primary	0.90	0.08	0.25	0.90	0.10	0.00	0.90	0.10	0.00
Married Secondary	0.42	0.32	0.26	0.41	0.33	0.25	0.42	0.32	0.25

Totals may not sum to 1 due to rounding

Table A3: Targeted and Baseline Actual Aggregate Ratios

Target Ratio	**Data**	**Model: ITC**	**Model: CTS**
Homeownership ratio	0.639 (AHS)	0.639	0.640
Private business investment to total private investment ratio	0.465 (BEA)	0.473	0.478
Private business investment to output ratio	0.162 (BEA)	0.163	0.162
Corporate gross interest expense to output ratio	0.039 (SOI/BEA)	0.038	0.038
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)	0.710	0.710

B Trend-Stationary Equilibrium

The model is transformed into trend-stationary form as described in Appendix B.1 of Moore and Pecoraro (2018b) 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 (2018b). 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 assets $\tilde{a}$, 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, while end-of-life expenditures $\tilde{c}^{eol}$ and accidental bequests $\tilde{beq}$ depend exogenously on a household's net worth state and the time of death.

Corporate and non-corporate 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 $\tilde{\Omega}^{z,f}_{t,j}$, a household value function $V^{z,f}_{t,j}(\tilde{y})$, a collection of household decision rules $\{\tilde{c}^{i;z,f}_{t,j}(\tilde{y}),\ \tilde{c}^{g;z,f}_{t,j}(\tilde{y}),\ n^{z,s}_{t,j}(\tilde{y}),\ n^{z,m,1}_{t,j}(\tilde{y}),\ n^{z,m,2}_{t,j}(\tilde{y}),\ \tilde{h}^{o;z,f}_{t,j}(\tilde{y}),\ \tilde{h}^{r;z,f}_{t,j}(\tilde{y}),\ \tilde{a}^{z,f}_{t,j}(\tilde{y});\ \tilde{y}^{z,f}_{t+1,j+1}(\tilde{y})\}$, 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:*

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

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

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

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

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

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

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

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

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

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

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

$$\tilde{w}_t = (1-\alpha-g)\tilde{G}_t^g(\tilde{K}_t^c)^\alpha(\tilde{N}_t^c)^{-\alpha-g} = (1-\alpha-g)\tilde{G}_t^g(\tilde{K}_t^n)^\alpha(\tilde{N}_t^n)^{-\alpha-g}$$

6. *The asset market clears such that:*

$$\tilde{D}_{t+1} = \tilde{V}_{t+1}^c + \tilde{V}_{t+1}^n + \tilde{B}_{t+1}^c + \tilde{B}_{t+1}^n + \tilde{B}_{t+1}^g + H_t^r + \tilde{H}_t^r(\Upsilon_P \Upsilon_A)^{-1}$$

where assets are priced to eliminate any arbitrage opportunities:

$$R_t^c = R_t^n = (1-\tau_t^i)i_t = (1-\tau_t^r)p_t^r - \delta^r$$

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

$$\rho_t = \varpi + \varsigma \exp\left(\frac{\tilde{B}_{t+1}^g \Upsilon_P \Upsilon_A - \tilde{B}_t^g}{\tilde{Y}_t} - \frac{\tilde{B}_{SS}^g(\Upsilon_P \Upsilon_A - 1)}{\tilde{Y}_{SS}} \right)$$

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:

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

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:

$$\tilde{txl}_t^{hh} = \int_{\mathbb{Z}}\int_{\mathbb{J}} \sum_{f=s,m} \left(\tilde{oit}_{t,j}^{z,f} + \tilde{cit}_{t,j}^{z,f} + \tau_t^{pr} \tilde{\hat{i}}_{t,j}^{z,f}\right)\tilde{\Omega}_{t,j}^{z,f}\ dj\ dz$$

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

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

and transfers are:

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

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:

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

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

10. The measure of households is time-invariant:

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

11. The net worth of households that die before reaching the maximum age J is allocated to end-of-life consumption expenditures to bequests among the living such that:

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

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

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.*