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Abstract

We use an overlapping generations model with endogenous avoidance and rich tax detail to quantitatively analyze two major issues in the design of a wealth tax for the United States: the provision of exclusions for certain housing and business equity, and the range of government expenditure options allowed for by additional revenues. First, we find that while the provision of an exclusion for owner-occupied housing results in quantitatively insignificant macroeconomic and budgetary effects, the provision of an exclusion for privately-held noncorporate business equity results in a shift of productive activity towards that sector and undermines the revenue-raising potential of the tax. Second, we find that the macroeconomic effects of a given wealth tax regime can vary from contractionary to expansionary depending on the type of expenditures that are assumed to be financed by the additional revenues.

JEL Codes: E62, H26, H27
Keywords: wealth tax; avoidance; budgetary feedback

*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

The renewed interest for direct taxation of top household wealth has generated macroeconomic analyses of wealth tax regimes for the United States. While much attention has been given to the effects of alternative statutory tax schedules, little attention has been given to the effects of two other major issues that policymakers would face when designing a wealth tax: (i) the provision of exclusions from the tax base for owner-occupied housing and privately-held noncorporate business equity that have been common in practice;[1,2] and (ii) the various expenditure options that could be financed using the additional revenues generated by the tax.[3] Because these design issues can drive avoidance and other real economic behavior,[4] a quantitative analysis is critical for understanding the range of possible macroeconomic and budgetary effects of a wealth tax for the United States.

In this paper we use an overlapping generations model calibrated to the United States to simulate variations to a stylized top-wealth tax through exclusion and expenditure options. Two particular features of this framework distinguish our analysis: First, avoidance occurs endogenously in the model. Households choose their wealth composition across financial and housing assets, enabling us to endogenously capture household-level avoidance induced by the presence of assets with preferential tax treatment. Firms operate as publicly-traded corporate and privately-held noncorporate entities, enabling us to endogenously capture firm-level avoidance induced by the presence of certain business equity with preferential tax treatment. Second, we incorporate rich detail pertaining to the underlying federal income tax system by embedding an individual tax calculator within the model. This enables us to capture interaction across tax provisions and carefully account for the budgetary feedback that occurs in general equilibrium.

As a benchmark scenario for our analysis, we consider a broad-based 1% direct tax on wealth exceeding the top 1% individual tax-unit threshold, where additional revenues generated by the tax are used to pay down existing federal debt. We first make variations to this benchmark by providing exclusions for owner-occupied housing and privately-held noncorporate equity in a static revenue-consistent fashion. We find that while avoidance due to the housing exclusion results in quantitatively insignificant macroeconomic and budgetary effects, avoidance due to the noncorporate equity exclusion results in a 3.6% shift in productive activity from the corporate to noncorporate sector after three decades because of the implied production-level tax distortion. Relative to the benchmark sce-

[1]See OECD (2018) for a summary of assets excluded from wealth tax bases for OECD countries.

[2]We highlight housing and business equity exclusions in particular because they are common due to administrative difficulties, particularly for valuation, (Batchelder and Kamin, 2019; Kopczuk, 2019; Advani et al., 2020; Wetzler, 2020; Cochrane, 2020; Wolff, 2020; Alstadsæter et al., 2022) or political difficulties (Viard, 2019). Saez and Zucman (2019) discuss proposals to address these difficulties.

[3]While recognizing the fungibility of tax revenue, we emphasize that additional revenues must be accounted for by some change to the government's budget in the form of spending on goods, tax cuts, or debt reduction. We therefore use 'expenditure' in a broad sense to refer to such budgetary offsets.

[4]See Alvaredo and Saez (2010), Durán-Cabré et al. (2019), and Scheuer and Slemrod (2021).

nario, the noncorporate equity exclusion scenario raises 14.8% less annual tax revenue on average over three decades. Additionally, we emphasize that this particular avoidance behavior is distinct from evasion behavior via under-reporting wealth.

Next, we show that the macroeconomic effects of a given wealth tax depend on how the additional revenues generated by the tax are used. Rather than assuming that additional revenues generated by the wealth tax are used to reduce outstanding federal debt, we allow for three alternatives to be paired with the broad-based tax: creation of a Universal Basic Income (UBI) transfer program, an expansion of the standard deduction within the federal income tax system, and investment in public infrastructure. We find that the wealth tax is most expansionary when additional revenues are dedicated to public infrastructure investment, as the initial positive output effects from public investment feed back into the federal budget via increased federal income tax revenue, allowing for increasing amounts of public capital over three decades. Conversely, we find that the wealth tax is most contractionary in the UBI transfer scenario, where initial negative output effects from a reduction in labor reduces federal income tax revenue, subsequently reducing the amount of revenue available for transfers over three decades.

This paper lies at the intersection of two strands of literature. First, as we quantitatively characterize household-level saving responses to a wealth tax, our paper is related to the applied microeconomic analyses of Alvaredo and Saez (2010), Seim (2017), Durán-Cabré et al. (2019), Jakobsen et al. (2020), Brülhart et al. (2022), and Alstadsæter et al. (2022). Of this group, our analysis is most similar to Jakobsen et al. (2020) through the shared use of structural lifecycle modeling to decompose short- and long-run behavioral effects across different groups of households. However, we echo Alstadsæter et al. (2022) in highlighting that such behavioral responses are sensitive to the design of the wealth tax. Second, as we incorporate general equilibrium effects, our paper is also related to the structural macroeconomic simulation analyses of DeBacker et al. (2018), Kaymak and Poschke (2019), Penn-Wharton Budget Model (2019), Penn-Wharton Budget Model (2020), Diamond and Zodrow (2020), Rotberg and Steinberg (2022), and Guvenen et al. (2022). While this prior work is focused on the statutory schedule of a wealth tax, we instead focus on the tax base. In addition, we seek to highlight how the macroeconomic effects of a given wealth tax are sensitive to the various assumptions about revenue usage employed in this prior work.[5]

[5]While expenditure assumptions have varied across existing macroeconomic analyses, this variation not been systematic. In particular, additional revenues are used for transfers in DeBacker et al. (2018), Rotberg and Steinberg (2022), and Diamond and Zodrow (2020); debt reduction in Penn-Wharton Budget Model (2020), Penn-Wharton Budget Model (2019), and Diamond and Zodrow (2020); and income tax reduction in Kaymak and Poschke (2019), Rotberg and Steinberg (2022), and Guvenen et al. (2022). Only in Diamond and Zodrow (2020) and Rotberg and Steinberg (2022) are two alternative assumptions been tested as a sensitivity check.

2 The Model

The fundamental structure of the model used in this paper is based on Moore and Pecoraro (2021):[6] Overlapping generations of heterogeneous and finitely-lived households make consumption, labor supply, and residential choices to maximize their lifetime utility. Corporate and noncorporate business entities make labor demand and capital investment choices to maximize firm value. While households and firms directly interact in labor and goods markets, financial intermediaries pool financial wealth from households and allocate these resources into a portfolio of private business equity and debt, as well as public debt issued by the federal government. Federal, state, and local taxes are levied both at the household and business levels as specified under present law. Household tax liabilities at the federal level are determined by an internal tax calculator, which explicitly models key provisions of the Internal Revenue Code.

With a top-wealth tax for the United States as the object of interest in the present paper, it is crucial that our model reproduces the observed concentration of household wealth. We therefore adopt the 'capitalist spirit' specification of wealth-in-the utility-function (WIU) introduced by Carroll (2002). Households with WIU receive a 'warm-glow' from their accumulated wealth, as it is a direct argument in their utility function. De Nardi and Fella (2017) demonstrate that the incorporation of utility from wealth resolves some of the difficulties involved with endogenously reproducing realistic wealth concentration within dynamic quantitative models.[7] While it is common to specify a bequest motive for this purpose (DeBacker et al., 2018; Jakobsen et al., 2020), we instead follow Francis (2009) and employ a generalized WIU specification so that we can remain agnostic about the specific reason for WIU to arise.[8]

2.1 Households

The economy is populated by J overlapping generations of finitely-lived households who are ex ante heterogeneous by family composition of single or married $f = \{s, m\}$, ages $j = \{1, \ldots, J\}$, and labor productivity types $z = \{1, \ldots, Z\}$, and who are ex-post heterogeneous by wealth and by residential status as a homeowner or renter.[9] Working-age households of $j = \{1, \ldots, R-1\}$ survive each period with a unitary conditional probabil-

[6] The model described in the current paper reflects a version of the overlapping generations 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. See Joint Committee on Taxation (2020).

[7] Alternative methods for endogenously generating realistic wealth concentration include incorporating stochastic earnings with a 'superstar' state (Castañeda et al., 2003), entrepreneurship Cagetti and De Nardi (2006), or heterogeneous returns (Hubmer et al., 2020).

[8] It has been argued that WIU may also arise from non-pecuniary benefits of entrepreneurship, social status, or political influence (Saez and Stantcheva, 2018; Michaillat and Saez, 2021).

[9] As described in Appendix B.1.5, we allow households of a given (f, z) demographic to vary by initial wealth endowments $e = \{1, \ldots, E\}$. Since household decision rules do not depend on this dimension, we omit indexing by e to reduce notational clutter.

ity $\pi_{j<R} = 1$, while retired households of $j = \{R, \ldots, J\}$ face mortality risk each period with conditional probabilities $0 < \pi_{j>=R} < 1$ and $\pi_J = 0$. In each period t, the measure of households for a given (f, z, j) demographic is denoted by $\Omega^{f,z}_{t,j}$, where the mass of new entrants grows exogenously at the gross rate of Υ_P across periods.

We specify distinct single and married households to capture the dependence of underlying federal tax provisions on family composition. Each household has an associated value function $V^{f,z}_{t,j}$ that is increasing in two individual state variables — real financial assets, a_j, and real owner-occupied housing assets, h^o_j — the sum of which is total wealth, $y_j \equiv a_j + h^o_j$. The composition of total wealth across each asset type is endogenous, which facilitates household-level tax avoidance when either asset becomes relatively more tax-preferred. Instantaneous utility is generated through the function $U^{f,z}_{t,j}$ — which is increasing in a household's real consumption of a composite good[10] x_j, and decreasing in the labor hours n_j of each adult in a household — and through the function O_t — which is increasing and non-homothetic in a household's end-of-period total real wealth, y_{j+1}. The optimization problems for single and married households under a known policy regime are:

$$V^{s,z}_{t,j}(a_j, h^o_j) = \max_{\substack{a_{j+1}, h^o_{j+1}, x_j, \\ n_j \in \mathbb{N}}} U^{s,z}_{t,j}(x_j, n_j) + O_t(y_{j+1}) + \beta \pi_j V^{s,z}_{t+1,j+1}(a_{j+1}, h^o_{j+1}) \tag{2.1}$$

$$V^{m,z}_{t,j}(a_j, h^o_j) = \max_{\substack{a_{j+1}, h^o_{j+1}, x_j, \\ n^1_j, n^2_j \in \mathbb{N}}} U^{m,z}_{t,j}(x_j, n^1_j, n^2_j) + O_t(y_{j+1}) + \beta \pi_j V^{m,z}_{t+1,j+1}(a_{j+1}, h^o_{j+1}) \tag{2.2}$$

where β is a subjective discount factor.[11]

To economize on the state-space of our model, we specify that each adult member of a working-age household chooses between part-time work, full-time work, or no work such that $n_j \in \mathbb{N} \equiv \{0, n^{PT}, n^{FT}\}$.[12] Under this specification of labor indivisibility, individual labor supply choices operate under a reservation wage framework (Chang and Kim, 2006). So that our model exhibits plausible lifecycle employment properties, we incorporate sources of reservation wage heterogeneity related to child-rearing in the spirit of Guner et al. (2012) and Guner et al. (2020). Letting $\nu^{f,z}_j$ denote a household's number

[10] So that we can model the tax detail involved with tax-preferred consumption choices, the composite consumption good x_j includes endogenous optimal quantities for consumption of market goods, housing services from either a rental unit or an owned home, services produced at home using time not spent on market labor or child-care, and charitable giving. For purposes of exposition, we explain this consumption detail in Appendix A.

[11] The structure of the dynamic programming problems imply that households do not consider the possibility of marriage or divorce. As described in Appendix B.1.1, we nonetheless allow for exogenous age-variation in the measure of single and married households.

[12] The household federal tax environment described in Section B.4.1 requires discrete evaluation of tax liabilities at each possible level and composition of income across capital and labor. The indivisible labor supply specification is adopted here to reduce the number of grid point combinations that must be evaluated relative to a continuous labor supply specification.

of (fractional) dependent children, employment interacts with: (*i*) a variable monetary child-care cost, $\kappa_j^{f,z}(\nu_j^{f,z}, n_j)$, which is a function of a household's number of dependents and the market work hours of the single or married-secondary workers; (*ii*) a fixed utility cost, $F_j^{f,z}(\nu_j^{f,z}, n_j)$, which is positive only when the single or married-secondary worker is employed; and (*iii*) nonlinear time-use for child-rearing, $\varphi_j^{f,z}(\nu_j^{f,z})$, which increases the marginal disutility of market labor for single and married-secondary workers in a nonlinear fashion. To be consistent with a balanced growth path in the presence of the fixed utility cost, we use the following functional form for instantaneous utility $U_{t,j}^{f,z}$:

$$U_{t,j}^{s,z}(x_j, n_j) \equiv \log(x_j) - \psi^s \frac{(n_j + \varphi_j^{s,z})^{1+\zeta^s}}{1+\zeta^s} - F_j^{s,z} \tag{2.3}$$

$$U_{t,j}^{m,z}(x_j, n_j) \equiv \log(x_j) - \psi^{m,1} \frac{(n_j^1)^{1+\zeta^{m,1}}}{1+\zeta^{m,1}} - \psi^{m,2} \frac{(n_j^2 + \varphi_j^{m,z})^{1+\zeta^{m,2}}}{1+\zeta^{m,2}} - F_j^{m,z} \tag{2.4}$$

We adopt a wealth-in-utility specification so that our model can reproduce the empirically observed level of wealth concentration (Carroll, 2002; Francis, 2009). In doing so we assume that this function non-homothetic in total wealth:

$$O_t(y_{j+1}) \equiv \log\left(y_{j+1}/o_{t+1} + 1\right) \tag{2.5}$$

where the parameter o_t determines the extent to which wealth is a luxury good (De Nardi, 2004), and depends on time only through exogenous growth at the gross rate of technical progress, Υ_A.

In every period of life, a household's choices are restricted by the following real budget constraint:

$$p_t^x x_j + a_{j+1} + h_{j+1}^o \leq (1+r_t^p)a_j + (1-\delta^o)h_j^o + inh_{t,j}^{f,z} + i_{t,j}^{f,z} - \mathcal{T}_{t,j}^{f,z} - \kappa_j^{f,z} - \xi_j^H \tag{2.6}$$

where variables on the left-hand side are consumption expenditures of the composite good $p_t^x x_j$, end-of-period financial assets a_{j+1} and end-of-period owner-occupied housing assets h_{j+1}^o, and variables on the right-hand side are the gross return to beginning-of-period financial assets $(1+r_t^p)a_j$, beginning-of-period owner-occupied housing assets net of economic depreciation $(1-\delta^o)h_j^o$, inheritances $inh_{t,j}^{f,z}$, non-capital income $i_{t,j}^{f,z}$, net tax liabilities $\mathcal{T}_{t,j}^{f,z}$, child-care expenditures $\kappa_j^{f,z}$, and housing transaction costs ξ_j^H. A household that enters the economy in any given period is assumed receives an exogenous endowment of financial wealth, but no owner-occupied housing:

$$a_1 = \bar{a}, \quad h_1 = 0 \tag{2.7}$$

Regardless of residential status, a household is permitted to borrow and have negative total wealth up to $\underline{y}^{f,z} < 0$. In order to purchase a residence, a household must have a minimum down payment ratio of $1 > \gamma > 0$. As in Gervais (2002), we allow for homeowners to use their housing as collateral for borrowing as long as the minimum equity ratio is maintained:

$$a_j \geq \begin{cases} \underline{\mathrm{y}}^{f,z} & \text{if } h_j^o = 0 \\ \max\{\underline{\mathrm{y}}^{f,z}, (\gamma - 1)h_j^o\} & \text{if } h_j^o > 0 \end{cases} \tag{2.8}$$

We assume that there is an institutional minimum size of owner-occupied housing equal to $\underline{\mathrm{h}}^o$; a household that is unable to afford at least $\underline{\mathrm{h}}^o$ will instead rent housing. The housing transaction cost ξ_j^H is positive only when a household chooses to change their residential status from a renter to homeowner, or vice versa, in the subsequent period. As described in Appendix A, consumption of both owner-occupied and rental housing services are nested in the composite good x_j.

Non-capital income is equal to labor income during working ages and equal to social security income $ss_j^{f,z}$ during retirement:

$$i_{t,j}^{f,z} \equiv \begin{cases} n_j w_t \mathrm{z}_j^{s,z} + ss_j^{s,z} & \text{if} f = s \\ (n_j^1 + \mu^z n_j^2) w_t \mathrm{z}_j^{m,z} + ss_j^{m,z} & \text{if} f = m \end{cases} \tag{2.9}$$

where w_t is the market real wage rate, $\mathrm{z}_j^{f,z}$ 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.

A household's net tax liability $\mathcal{T}_{t,j}^{f,z}$ is equal to the sum of their federal income and payroll tax liability, $\mathcal{T}_t^{\boldsymbol{i}}(i_{t,j}^{f,z}, r_t^p a_j)$, their federal tax liability on wealth, $\mathcal{T}_t^{\boldsymbol{w}}(h_j^o, a_j)$, and their state-local income, sales, and property tax liability, $slt_{t,j}^{f,z}$, less federal transfer payments, trs_t:

$$\mathcal{T}_{t,j}^{f,z} = \mathcal{T}_t^{\boldsymbol{i}}(i_{t,j}^{f,z}, r_t^p a_j) + \mathcal{T}_t^{\boldsymbol{w}}(h_j^o, a_j) - trs_t + slt_{t,j}^{f,z} \tag{2.10}$$

While households in the model do not undertake estate planning for tax minimization purposes, the estate of a household that dies at age $\underline{j}$ is assumed to be apportioned across end-of-life expenditures, $c_{\underline{j}}^E$, estate tax liabilities, $\mathcal{T}_t^{\boldsymbol{est}}(y_{\underline{j}+1})$, and bequests, $beq_{\underline{j}}$ to descendants prior to the start of the next period. This apportionment process described in Appendix B.1.4.

2.2 Firms

Output of the numéraire good is produced by firms across two perfectly competitive sectors — corporate and noncorporate, $q = c, n$ — and can be transformed by economic agents into consumption goods and services or investment assets. Firms finance investment in capital K_t^q using a combination of bonds and equity obtained from the financial market, hire labor input N_t^q from perfect labor markets, and use these inputs to produce output Y_t^q at value maximizing levels. The primary differences between firms in the corporate and noncorporate sector are in terms of tax treatment, the distribution of profits, and new equity share issuance.

We define the real after-tax return on the equity value of the representative firm in each sector, $R_t^q V_t^q$, as the sum of aggregate net capital gains and net income to the marginal investor-household:

$$V_t^c R_t^c = (1-\tau_t^g) gns_t^c + (1-\tau_t^d) div_t \tag{2.11}$$

$$V_t^n R_t^n = (1-\tau_t^g) gns_t^n + dst_t - txl^n \tag{2.12}$$

where τ_t^g is the aggregate accrual-equivalent tax rate on capital gains gns_t^q, τ_t^d is an aggregate effective marginal tax rate on corporate dividends div_t, and txl^n is the federal tax liability on noncorporate distributions dst_t. Pretax capital gains are equal to the change in firm value:

$$gns_t^c = V_{t+1}^c - V_t^c - shr_t \tag{2.13}$$

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

where the corporate firm is assumed publicly traded so that it can issue or buy back shares of equity shr_t, and the noncorporate firm is assumed to be privately held so that it cannot issue or buy back equity shares.[13]

The objective function for the representative firm in each sector can be obtained by substituting equations (2.13) and (2.14) into equations (2.11) and (2.12) respectively, rearranging for V_t^q, and solving forward:

$$V_t^c(K_t^c) = \max_{N_t^c, K_{t+1}^c} \frac{(1-\tau_t^d) div_t - (1-\tau_t^g) shr_t}{(R_t^c + 1 - \tau_t^g)} + \beta_t^c V_{t+1}^c(K_{t+1}^c) \tag{2.15}$$

$$V_t^n(K_t^n) = \max_{N_t^n, K_{t+1}^n} \left(\frac{dst_t - txl^n}{R_t^n + 1 - \tau_t^g} \right) + \beta_t^n V_{t+1}^n(K_{t+1}^n) \tag{2.16}$$

where $\beta_t^q \equiv \frac{(1-\tau_t^g)}{(R_t^q + 1 - \tau_t^g)}$ for $q = c, n$. Each firm is constrained by:

1. the cash flow restriction:

$$ern_t^c + B_{t+1}^c - B_t^c + shr_t = div_t + I_t^c + txl_t^c + slt_t^c \tag{2.17}$$

$$ern_t^n + B_{t+1}^n - B_t^n = dst_t + I_t^n \tag{2.18}$$

[13] Since we do not model privately-held corporate entities or publicly-held noncorporate entities, avoidance on the public-private margin is the same as avoidance on the corporate-noncorporate margin.

2. the law of motion for capital:

$$K_{t+1}^q = (1-\delta^K)K_t^q + I_t^q - \Xi_t^q \quad \text{for } q = c, n \tag{2.19}$$

where δ^K is the economic rate of depreciation on private capital and Ξ_t^q is an investment adjustment cost function.

3. the debt issues rule:

$$B_t^q = \varkappa^{b,q} K_t^q \quad \text{for } q = c, n \tag{2.20}$$

where $\varkappa^{b,q}$ is time-invariant debt-to-capital ratio and B_t^q is the beginning-of-period stock of net debt held by the representative firm in sector.

4. the dividend payout rule for the corporate firm in equation (2.21) described below.

The corporate firm's cash-flow restriction in equation (2.17) states that contemporaneous 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-local tax liabilities slt_t^c. As in Zodrow and Diamond (2013), we assume that the corporate dividends are an exogenous fraction $\varkappa^d$ of after-tax earnings:

$$div_t = \varkappa^d(ern_t^c - txl_t^c - slt_t^c) \tag{2.21}$$

The noncorporate firm's cash-flow restriction in equation (2.18) differ from that of the corporate firm to the extent that noncorporate firms do not issue new equity shares and do not directly remit tax liabilities to the government.[14] Although the noncorporate firm internalizes the tax liabilities generated by its activity into its own value as specified in equation (2.16), the tax liabilities are ultimately remitted to the government by investor-households. As described in Section 2.3, pretax noncorporate distributions dst_t are passed through to the household-level where they are taxed jointly with other household income.

Earnings for firms in both sectors are defined as production of output, Y_t^q, less wages paid to labor input, $w_t N_t^q$ and interest paid on debt $i_t B_t^q$:

$$ern_t^q \equiv Y_t^q - w_t N_t^q - i_t B_t^q \quad \text{for} \quad q = c, n \tag{2.22}$$

Output is produced using constant returns to scale, Cobb-Douglas technology:

$$Y_t^q = Z^q (G_t)^g (K_t^q)^\alpha (A_t N_t^q)^{1-\alpha-g} \quad \text{for} \quad q = c, n \tag{2.23}$$

where $G_t = G_t^{fed} + G_t^{sl}$ is beginning-of-period public capital from federal, state and local governments, K_t^q and N_t^q are beginning-of-period productive private capital and effective

[14]This assumption reflects the current tax treatment of noncorporate entities in the United States.

labor employed in each sector, Z^q is a scale parameter, and A_t is labor-augmenting technology that evolves identically within each sector according to $A_{t+1} = \Upsilon_A A_t$. The decreasing returns to scale for private factors of production allows for an interior solution with the two sector - single output good framework. In addition, the public factor input along with perfect financial and labor markets leads to economic rents which are fully captured by firms.

2.3 Financial Intermediaries

While households directly choose the allocation of their wealth between real and financial assets, financial intermediaries are assumed to allocate household financial wealth across available investment vehicles. To obtain a no-arbitrage condition that characterizes an optimal aggregate allocation in the financial market, we specify an overlapping generations structure of perfectly competitive, two-period-lived financial intermediaries: In the first period of a representative financial intermediary's life, it collects end-of-period savings from households as deposits, D_{t+1}, and chooses a portfolio that consists of corporate and noncorporate equity V^c_{t+1} and V^n_{t+1}, corporate and noncorporate bonds B^c_{t+1} and B^n_{t+1}, domestically-held federal government bonds B^g_{t+1}, and rental housing H^r_{t+1}. In the second period of its life, a representative financial intermediary passes the pretax portfolio returns $r^p_{t+1} D_{t+1}$ back to households and transfers its remaining assets to a new representative financial intermediary which repeats this process.

There is assumed to be no investment risk so that the real returns of each investment vehicle are known with certainty. First, corporate and noncorporate equity pays dividends div_{t+1} and distributions dst_{t+1}, and accrues capital gains gns^c_{t+1} and gns^n_{t+1}. Second, corporate and noncorporate bonds yield a pretax rate of return of i_{t+1}, while government bonds yield a low, "safe" pretax rate of return ρ_{t+1}, which depends positively on both the private bond rate and the total public debt-output ratio:

$$\rho_{t+1} = \varpi i_{t+1} + \varsigma \exp\left(\frac{B^{g,tot}_{t+1}}{Y_{t+1}}\right) \quad \forall t \tag{2.24}$$

Finally, following Gervais (2002) and Francis (2009), it is assumed that financial intermediaries have access to technology that can transform deposits into rental housing services. The stock of rental housing services held by a financial intermediary are rented out to households at a price of p^r_{t+1} and depreciate at rate δ^r. The total income received by a representative financial intermediary from its portfolio allocation can be summarized as:

$$Inc_{t+1} \equiv div_{t+1} + dst_{t+1} + gns^c_{t+1} + gns^n_{t+1} + (p^r_{t+1} - \delta^r) H^r_{t+1} + \rho_{t+1} B^g_{t+1} + i_{t+1}(B^c_{t+1} + B^c_{t+1}) \quad \forall t \tag{2.25}$$

Formally, the maximization problem for a representative financial intermediary is:

$$\max_{\substack{V^c_{t+1}, V^n_{t+1}, \\ B^c_{t+1}, B^n_{t+1}, H^r_{t+1}}} \quad Inc_{t+1} - r^p_{t+1} D_{t+1} \tag{2.26}$$

subject the financial market resource constraint:

$$D_{t+1} = V^c_{t+1} + V^n_{t+1} + B^g_{t+1} + B^c_{t+1} + B^n_{t+1} + H^r_{t+1} \quad \forall t \tag{2.27}$$

Perfect competition in the financial market implies a zero-profit condition each period so that households receive a pretax portfolio return on their deposits equal to:

$$r^p_{t+1} = \frac{Inc_{t+1}}{D_{t+1}} \quad \forall t \tag{2.28}$$

which is equivalently the borrowing rate for debtor households. For the portfolio allocation to be optimal in the aggregate, the average tax consequences of households must be internalized by financial intermediaries. The no-arbitrage condition will therefore reflect equalization of the aggregate after-tax marginal rates of return across investment vehicles:

$$R^c_{t+1} - \tau^{cw}_{t+1} = R^n_{t+1} - \tau^{nw}_{t+1} = (1 - \tau^i_{t+1}) i_{t+1} - \tau^{bw}_{t+1} = (1 - \tau^r_{t+1})(p^r_{t+1} - \delta^r) - \tau^{rw}_{t+1} \quad \forall t \tag{2.29}$$

where R^c_{t+1} and R^n_{t+1} are the rates of return to corporate and noncorporate equity net of income taxes, τ^i_{t+1} and τ^r_{t+1} are aggregate effective marginal tax rates on interest and rental income, and τ^{cw}_{t+1}, τ^{nw}_{t+1}, τ^{bw}_{t+1}, τ^{rw}_{t+1} are aggregate effective marginal tax rates on corporate and noncorporate equity wealth, bond wealth, and rental housing wealth.

The financial market no-arbitrage condition (2.29) plays a crucial role in endogenously generating firm-level tax avoidance when certain business assets become tax-preferred: Under a broad-based wealth tax, the aggregate effective marginal wealth tax rates on all investment vehicles would be equal and the relative rates of return are unaffected by the presence of a wealth tax. If instead an exclusion is provided for assets associated with a particular sector, there would be an equilibrium differential in the associated aggregate effective marginal wealth tax rates and thus the rates of return across investment vehicles. This distortion generates a cross-sector asymmetry in firms' discount rates which shifts in productive activity towards the tax-preferred sector.

2.4 Government

2.4.1 Federal

The federal government collects taxes from households and firms, T^{fed}_t, and makes bond issuance $B^{g,tot}_{t+1} - B^{g,tot}_t$ to finance public consumption, C^{fed}_t, productive capital expenditures, I^{fed}_t, and transfer payments to households TR^{fed}_t. The recursive budget constraint of the federal government can then be expressed as:

$$I_t^{fed} + C_t^{fed} + TR_t^{fed} \leq T_t^{fed} + B_{t+1}^{g,tot} - (1+\rho_t)B_t^{g,tot} \tag{2.30}$$

While federal government consumption is assumed to be non-valued by households, federal public capital is assumed to be productive as specified in equation (2.23). To account for the time-to-build properties of public capital (Ramey, 2020; Leeper et al., 2010), the law of motion for federal public capital follows:

$$G_{t+1}^{fed} = (1-\delta^g)G_t^{fed} + \sum_{s=1}^{S} \kappa_s^{fed} I_{t-s+1}^{fed} \tag{2.31}$$

where δ^g is the rate of economic depreciation on public capital, S is the number periods it takes for public capital investment to become fully productive, and $\sum_{s=1}^{S} \kappa_{s-1}^{fed} = 1$.

Total taxes collected by the federal government include those from households, txl_t^{hh}, corporations, txl_t^c, and estates txl_t^{est}:

$$T_t^{fed} \equiv txl_t^{hh} + txl_t^c + txl_t^{est} \tag{2.32}$$

Taxes collected on estates are levied on the wealth left by decedent households:

$$txl_t^{est} = \int_{\mathbb{Z}} \int_{\mathbb{J}} (1-\pi_j) \sum_{f=s,m} \mathcal{T}_t^{\boldsymbol{est}}(y_{j+1}) \Omega_{t,j}^{f,z} \; dj \; dz \tag{2.33}$$

Taxes collected from households, txl_t^{hh}, consist of tax liabilities on income and wealth:

$$txl_t^{hh} = \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \Big(\mathcal{T}_t^{\boldsymbol{i}}(i_{t,j}^{f,z}, r_t^p a_j) + \mathcal{T}_t^{\boldsymbol{w}}(h_j^o, a_j) \Big) \Omega_{t,j}^{f,z} \; dj \; dz \tag{2.34}$$

As distinguishing feature of our framework, each household's federal income taxes contained in the object $\mathcal{T}_t^{\boldsymbol{i}}(i_{t,j}^{f,z}, r_t^p a_j)$ are determined by an internal tax calculator that explicitly models key provisions of the Internal Revenue Code. For example, as described in Section 2.2, tax liabilities generated by noncorporate business activity are passed through the firm to its owners. Our internal tax calculator determines each household's tax liability on this noncorporate income jointly with any other ordinary income as under specified present-law, and checks eligibility for various deductions and credits that depend on family composition and tax-preferred consumption choices. Moore and Pecoraro (2020b) and Moore and Pecoraro (2021) argue that this approach dominates the conventional specification of smooth tax functions in terms of capturing interaction and conditionality among tax provisions, thus better accounting for budgetary feedback that occurs in general equilibrium. The internal tax calculator is described in Appendix B.4.1.

In addition to social security payments to retirees, $ss_{t,j}^{f,z}$, households receive lump-sum transfer payments from the federal government, trs_t. Aggregate federal government transfers therefore can be expressed as:

$$TR_t^{fed} = \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \left(ss_{t,j}^{f,z} + trs_t \right) \Omega_{t,j}^{f,z} \; dj \; dz \tag{2.35}$$

To capture partial financing of budget deficits by foreign agents, we assume that domestic agents only purchase an exogenous fraction of total new debt issued:

$$B_{t+1}^g - B_t^g = \kappa^{dom}(B_{t+1}^{g,tot} - B_t^{g,tot}) \tag{2.36}$$

where it is implied that foreign agents outside the model purchase the residual. This partially-open-economy specification reduces the sensitivity of the model to 'crowding-out' or 'crowding-in' effects following large changes to federal debt. We rule out explosive debt paths by maintaining the no-Ponzi condition:

$$\lim_{k \to \infty} \frac{B_{t+k}^{g,tot}}{\prod_{s=0}^{k-1}(1 + \rho_{t+s})} = 0 \tag{2.37}$$

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

2.4.2 State and Local

Composite state and local government tax receipts, T_t^{sl}, are used to finance non-valued consumption, C_t^{sl}, and productive capital expenditures I_t^{sl}. We specify an intraperiod balanced-budget constraint:

$$I_t^{sl} + C_t^{sl} = T_t^{sl} \tag{2.38}$$

State-local public capital, which is included in the model to account for state-local offsets to changes in federal public capital (Congressional Budget Office, 2021, 2016), follows the law of motion:

$$G_{t+1}^{sl} = (1 - \delta^g)G_t^{sl} + I_t^{sl} \tag{2.39}$$

with the reaction function:

$$I_t^{sl} = I^{sl} - \kappa^{sl} \left(I_t^{fed} - I^{fed} \right) \tag{2.40}$$

where I^{sl} and I^{fed} are the steady state levels of state-local and federal government investment in public capital. Equation 2.40 implies that state-local public capital investment is reduced below its steady state level by κ^{sl} for every unit that the federal government's public capital investment is above its own steady state level.

Total tax revenue at the state-local level is the sum of aggregate taxes collected from households and corporations:

$$T_t^{sl} \equiv \int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} slt_{t,j}^{f,z} \Omega_{t,j}^{f,z} + slt_t^c \; dj \; dz \tag{2.41}$$

2.5 Equilibrium

Equilibrium is informally defined as a collection of decision rules that are the solutions to households' and firms' optimization problems; a collection of economic aggregates that are consistent with household and firm behavior; a collection of prices that facilitate cross-sector factor-price equalization and clearing in factor, asset, and goods markets; and an associated set of policy aggregates that are consistent with government budget constraints. Equilibrium is formally defined in Appendix C in terms of a trend-stationary transformation of the model.

3 Calibration

The initial steady state balanced growth path is calibrated at an annual frequency to approximate the 2017 economic environment and tax law, which is the baseline against which our policy experiments are measured.[15] The choice of parameter values largely follows from Moore and Pecoraro (2021), which makes use of long-run historical data, recent observations, micro-studies, and projections. In particular, most projections used in our calibration procedure are either obtained from the Joint Committee on Taxation's Individual Tax Model ("JCT-ITM")[16] or *The Budget and Economic Outlook: 2018 to 2018* from the Congressional Budget Office ("CBO"). In the following sections, we describe the properties of our initial steady state household wealth distribution and the computation of household wealth taxes. Our broader initial steady state calibration strategy and income tax framework are described in Appendix B

3.1 Baseline Wealth Distribution

In order for us to obtain reliable quantitative estimates of the macroeconomic and budgetary effects of a top-wealth tax for the United States, it is crucial that the endogenous

[15] In doing so, we do not incorporate the tax provisions contained in PL 115-97, also known as the 'Tax Cuts and Jobs Act', or the economic consequences of the Covid-19 pandemic and related policy measures such as the CARES Act of 2020, the Consolidated Appropriations Act of 2021, the American Rescue Plan of 2021, or the Inflation Reduction Act of 2022.

[16] Joint Committee on Taxation's Individual Tax Model is in principle similar to NBER's TAXSIM model. However, while TAXSIM makes use of the Statistics of Income ("SOI") division public use files, the JCT-ITM generally uses a more 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 Joint Committee on Taxation (2015).

wealth distribution in our model reflects key empirical properties. The top panel of Table 1 shows that the share of wealth held by the top 10%, 1%, and 0.1% tax units in our model's initial steady state baseline falls within the range of estimates from Smith et al. (2022) and Saez and Zucman (2020).[17,18,19] Similarly, the bottom panel of Table 1 show that the wealth thresholds for each top-wealth class within our model's baseline are broadly consistent with the data.

When quantifying the effects of allowing exclusions to a wealth tax for owner-occupied housing and noncorporate equity, the composition of total household wealth within our model becomes important. We report this in two pieces: First, we show in Table 2 the endogenous composition of financial wealth in our baseline, which is homogeneous across households because the portfolio allocation is determined at the financial intermediary level as described in Section 2.3. Second, we show in Table 3 the endogenous portion of total household wealth held as financial assets in our baseline, which is heterogeneous across households because owner-occupied housing is chosen at the household level as described in Section 2.1. Since financial assets represent a greater portion of total household wealth at higher points in the wealth distribution, the housing-financial asset composition of wealth in our model varies across households.

While we do not explicitly target the composition of total household wealth by class, our model endogenously produces owner-occupied and noncorporate equity shares that are quite close to empirical estimates for the top 1% of tax units by wealth. In our model, the average tax unit in the top 1% holds 81.5% of their wealth in financial assets, with the 18.5% residual held in owner-occupied housing. Given that 29.5% of financial assets are held in the form of noncorporate equity, the average tax unit in the top 1% holds 29.5% $\times$ 81.5% = 24.0% of their wealth in noncorporate equity. This aligns with Smith et al. (2022), where it is estimated that 15.6% and 23.7% of wealth for the average tax unit in the top 1% is held in owner-occupied housing and noncorporate equity respectively.

3.2 Wealth Taxation

We specify that direct wealth taxes apply to households' beginning-of-period stock of assets. With a proportional, statutory tax rate of $\tau^{\boldsymbol{w}}$ on a broad base, a household's wealth tax liability is computed as follows:

$$\mathcal{T}_t^{\boldsymbol{w}}(h_j^o, a_j) = \max\left(\tau^{\boldsymbol{w}}(a_j + (1 - \kappa^{dur})h_j^o - \bar{y}), 0\right) \tag{3.1}$$

[17]Although households and tax units are equivalent within our model, we compare our model's estimates with those expressed in tax units. We do so because empirical estimates at the household level would incorporate cohabitation, for example, which we do not model.

[18]To be consistent with the data, our model computations exclude the implied portion of wealth that represents consumer durables.

[19]Tax-unit level estimates of Smith et al. (2022) obtained from private correspondence.

where $\bar{y}$ is the exogenous wealth tax threshold, κ^{dur} is the assumed share of consumer durables contained in housing, and $\tau^{\boldsymbol{w}} = 0$ only in the initial steady state baseline. We set $\kappa^{dur} = 0.283$, which is the average share of consumer durables in the stock of residential capital over 2007-2016 as measured by the Bureau of Economic Analysis.[20] Housing and noncorporate equity exclusions are provided by subtracting $(1 - \kappa^{dur})h_j^o$ and $\omega_t^{nw} a_j$ respectively from the wealth tax base, where ω_t^{nw} is the endogenous and time-varying portfolio share of financial assets held in the form of noncorporate equity.[21]

Since the financial intermediary internalizes the average tax implications for households when allocating deposits into investment portfolios, we must specify the aggregate effective marginal tax rates on wealth for purposes of the no-arbitrage condition (2.29). Let $\omega_t^{\mathcal{W}}$ be the time-varying endogenous portfolio share of financial assets held in the form of corporate equity ($\mathcal{W} = cw$), noncorporate equity, ($\mathcal{W} = nw$), bonds ($\mathcal{W} = bw$), or rental housing ($\mathcal{W} = rw$).[22] The aggregate effective marginal wealth tax rates applicable to each financial asset type, $\tau_t^{\mathcal{W}}$, are then computed as an asset-weighted effective marginal wealth tax rate over households:

$$\tau_t^{\mathcal{W}} = \frac{\int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \Omega_{t,j}^{f,z} \left(\tau_{t,j}^{\mathcal{W};f,z} \omega_t^{\mathcal{W}} a_j \right) \; dj \; dz}{\int_{\mathbb{Z}} \int_{\mathbb{J}} \sum_{f=s,m} \Omega_{t,j}^{f,z} \left(\omega_t^{\mathcal{W}} a_j \right) \; dj \; dz} \quad \text{for } \mathcal{W} = cw, nw, bw, rw$$

where $\tau_{t,j}^{\mathcal{W};f,z}$ is the effective marginal wealth tax rate on a given implied financial asset type for a household of (f, z, j) demographic.[23]

4 Policy Scenarios

We simulate the unexpected enactment of a broad-based, top-wealth tax in the United States, the net revenues from which are used for federal debt reduction. Treating this as our benchmark scenario, we compare the policy-induced macroeconomic and budgetary effects against those from two sets of alternative scenarios: In the first set of alternative scenarios, we simulate the provision of exclusions for owner-occupied housing and noncorporate equity respectively in a static revenue-consistent fashion. While both exclusions generate observable avoidance behavior, the noncorporate equity exclusion generates a shift in productive activity from the corporate to the noncorporate sector that undermines the revenue-raising potential of the wealth tax. Moreover, we emphasize that this avoidance behavior is distinct from evasion behavior due to under-reporting.

[20]We exclude the consumer durable share of housing from the wealth tax to be consistent with our calibration of the wealth distribution as described Appendix B.1.3.

[21]The portfolio share of a noncorporate equity may be computed directly as $\omega_t^{nw} \equiv V_t^{nc}/D_t$.

[22]Since each household has the same portfolio of financial assets chosen by the financial intermediary, endogenous portfolio shares $\mu_t^{\mathcal{W}}$ are uniform across households.

[23]A household's effective marginal tax rate is computed by increasing the holdings of a given financial asset type by 1%.

In the second set of alternative scenarios, we show that electing to reduce federal debt with additional revenues as under the benchmark policy is not an innocuous assumption by simulating different uses for net revenue raised by the broad-based wealth tax: the creation of an annual UBI transfer program; an expansion of the standard deduction within the federal income tax system; and investment in public infrastructure. We find that the projected macroeconomic effects of a given wealth can range from contractionary to expansionary depending how the additional revenues are spent. Out of the alternative expenditure options analyzed here, those expenditures that generate more budgetary feedback tend to have relatively more positive aggregate output effects.

4.1 Benchmark Policy: Broad-Based Wealth Tax

A household's wealth tax liability under the broad-based ("benchmark") policy is determined by a single tax rate of $\tau^{w} = 0.01$ applied to household wealth (excluding consumer durables) in excess of our model's initial steady state top 1% individual tax-unit threshold of $\bar{y}$ = \$4.109 million (in 2018 dollars). All federal revenue raised, inclusive of net revenue changes from existing sources in the underlying federal tax system, is used to pay down federal debt for the first 40 years following implementation. After 40 years, we allow non-valued government consumption to change as needed to stabilize the path of debt so that the no-Ponzi condition (2.37) holds.[24] The macroeconomic and budgetary effects for the first three decades following enactment of this policy are described below, and expressed in terms relative to the initial steady state baseline path ("baseline").

Effect on Household Wealth: The responses of household wealth and its subcomponents to this benchmark policy are shown in Figure 1, while the associated time paths of key prices are shown in Figure 2. In the series labeled 'No Exclusion', aggregate wealth initially increases by about 0.3% before beginning a continuous decline to about 1.6% below its baseline level at the end of three decades. While both subcomponents of household wealth subject to the tax under this scenario — financial assets (deposits) and owner-occupied housing — are below their baseline levels by about the same magnitude after three decades, the respective time paths differ substantially. This difference occurs because of the variation in behavioral responses across high-wealth households who are affected both by first-order tax changes and second-order price changes, and other households who are only affected by the price changes in general equilibrium.

For the 'Top-1%' group of households,[25] the savings disincentive from the tax dominates the savings incentive from the increase in the portfolio rate of return, as their total wealth continuously declines despite a compositional shift towards financial assets. The

[24] See Moore and Pecoraro (2020a) for a discussion of fiscal closing assumptions.

[25] To be consistent across time, our 'Top-1%' group are those who, in the absence of the wealth tax, would have had total wealth in excess of the wealth tax threshold.

increase in the portfolio rate of return and compositional shift are especially pronounced in the first year of the policy change as capital gains on equity are realized by shareholders immediately. This occurs because, in our deterministic model, firm value increases contemporaneously with news that the future reduction in long-run government debt channels more investment towards private capital. The portfolio rate of return remains elevated over three decades because debt reduction also implies that the portfolio share of (high return) private assets relative to (low return) public bonds continues to increase. The 'Bottom-99%' group of households accumulate more financial assets because of this savings incentive, and accumulate more housing because the increase in the real wage rate raises their permanent income.[26] Because total wealth increases only for this group of households, it is their behavior that drives the initial increase in aggregate wealth.

Effect on Productive Activity: The relative after-tax rates of return to the subcomponents of financial assets (e.g. corporate and noncorporate equity and bonds) are not directly affected by the presence of a wealth tax under the benchmark policy because the broad base implies that the aggregate marginal effective tax rates on wealth $\tau^{cw}_{t+1}, \tau^{nw}_{t+1}, \tau^{bw}_{t+1}$, and τ^{rw}_{t+1} are all equal and positive.[27] Figure 3 shows that without additional distortions introduced to the financial intermediary's portfolio allocation decision, the time paths of the private factors of production are roughly symmetric across sectors for the 'No Exclusion' case.

The reduction in aggregate household financial assets drives up the firms' borrowing rate over the the first decade. Consequently the capital stock falls below baseline levels in both sectors and reaches a trough of -0.3% in the aggregate after twelve years. This trend is reversed in the second decade as the positive effect of federal debt reduction on available resources dominates, bringing down the borrowing rate. Firms therefore increasingly substitute capital for labor in production, leaving aggregate private capital 1.3% above baseline and aggregate labor 1.2% below baseline at the end of three decades. Because the negative effect of labor on output dominates the positive effect of capital, aggregate output remains -0.2% below baseline after three decades.

Effect on Tax Revenue: Figure 4 shows the path of projected revenue changes under the benchmark 'No Exclusion' policy, with select cross-sections highlighted in Table 4. Annual wealth tax revenue is equal to about \$285 billion in the first year and \$423 billion in the thirtieth year, both in 2018 dollars. Despite the large and growing amount of revenue raised from this new source, decreases in revenue from other sources are offsetting. Figure 5 shows that while annual total federal tax revenue increases by about 7.7%

[26]Note that the nested structure of the composite consumption good x_j implies that housing services are a normal good along with non-housing goods.

[27]See financial market equilibrium condition (2.29).

over its baseline value in the first year of the policy, this gain falls to about 6.5% after three decades as a result of base erosion on all other revenue sources. Put differently, because the 30-year average annual amount of wealth tax and total tax revenue under the benchmark policy are about \$347 billion and \$284 billion respectively, such base erosion reduces the 30-year average annual net revenue increase by about 22.2%. Thus, accounting for budgetary feedback with respect to the underlying federal income tax system is crucial when estimating net revenue changes due to a wealth tax.

4.2 Alternative Tax Bases

4.2.1 Exclusions

We now simulate two alternative policies, where exclusions are provided for owner-occupied housing and privately-held noncorporate equity. These exclusions are made in our model by subtracting $(1-\kappa^{dur})h_j^o$ and $\omega_t^{nw}a_j$ respectively from the wealth tax base in equation (3.1), where ω_t^{nw} is the endogenous and time-varying portfolio share of financial assets held in the form of noncorporate equity. Holding constant the top-1% threshold of $\bar{y} = \$4.109$ million, we internally calibrate the tax rate in these two alternative scenarios so that static revenue-consistency with the benchmark policy is maintained. This is achieved at $\tau^{\boldsymbol{w}} = 0.0133$ and $\tau^{\boldsymbol{w}} = 0.0108$ for the noncorporate equity exclusion and housing exclusion policies respectively. As in the benchmark policy, all revenue raised from a given policy change is used to pay down outstanding federal government debt for the first 40 years following implementation.

Effect on Household Wealth: Each exclusion policy generates household-level avoidance behavior where those households subject to the wealth tax hold relatively more wealth in the tax-preferred asset class. This occurs endogenously in our model because households choose the composition of their wealth, a decision which becomes distorted in the presence of exclusions from the wealth tax. Relative to the benchmark policy, Figure 1 shows that the 'Top 1%' wealthiest households[28] hold about 2.1% more housing on average over three decades when housing is excluded from the wealth tax base, and about 1.0% more financial assets on average when noncorporate equity is instead excluded. Consequentially, the reduction in the time path of aggregate total household wealth is attenuated under each alternative policy scenario. Relative to the benchmark policy, aggregate total wealth is about 0.2% larger on average over three decades when housing is excluded from the wealth tax base, and about 0.5% larger on average when noncorporate equity is instead excluded.

[28] Our 'Top 1%' group remains constant across policies for consistency.

Effect on Productive Activity: While the time paths of the private factors of production are relatively symmetric across sectors when housing is excluded from the wealth tax base, they differ significantly when noncorporate equity is excluded, as shown in Figure 3. This occurs because the exclusion for noncorporate equity distorts the financial intermediary's portfolio allocation decision, as $\tau^{nw}_{t+1} = 0$ while $\tau^{cw}_{t+1} = \tau^{bw}_{t+1} = \tau^{rw}_{t+1} > 0$. With relatively cheaper financing costs for noncorporate firms when noncorporate equity is excluded from the wealth tax base, the noncorporate sector expands while the corporate sector contracts, consistent with the findings of Alvaredo and Saez (2010). In our simulation, this shift in productive activity amounts to a 3.6% increase in the noncorporate sector's share of total output (from 31.06% to 32.18%) after three decades.

The shift in productive activity that occurs when noncorporate equity is excluded from the wealth tax base acts as a drag on total tax revenue (discussed below). This results in a relatively higher time path of public debt that puts upward pressure on the firm borrowing rate, delaying and weakening the crowding-in effect on private capital. Relative to the benchmark policy, aggregate private capital is about 0.4% lower while aggregate labor is about 0.3% higher on average over three decades.[29] Because labor has a larger production elasticity, aggregate output increases relative to the benchmark scenario by about 0.1% on average.

Absent cross-sector distortions that ultimately reduce tax revenue, increase public debt, and discourage investment, the relatively higher time path of aggregate financial assets under the housing exclusion policy imply relatively more resources available for private investment. Relative to the benchmark policy, aggregate capital and labor are both elevated by about 0.2% and 0.3% on average over three decades, causing a positive effect on aggregate output, which is about 0.2% higher on average.

Effect on Tax Revenue:[30] Table 4 shows that average annual revenue raised from the wealth tax over three decades is $25 billion smaller than the benchmark scenario when housing is excluded from the wealth tax base, but $39 billion smaller per year when noncorporate equity is excluded. When considering changes to all sources of federal tax revenue, the difference under the housing exclusion policy shrinks to $6 billion per year while the difference under the noncorporate equity exclusion policy grows to $42 billion per year. Because each of these policies are revenue-consistent in a static fashion, these differences are entirely due to behavioral and macroeconomic effects that occur in general equilibrium.

Figures 4 and 5 show the time paths of tax revenue from each source. Because the housing exclusion policy raises more revenue from every other source relative to the bench-

[29] This is broadly consistent with Bjørneby et al. (2022), who find a positive causal relationship from a taxpayer's wealth tax liability and employment growth in their closely-held firm using Norwegian data.

[30] All dollar figures are in 2018 dollars.

mark policy, the smaller amount collected directly from the wealth tax is responsible for the smaller amount of total tax revenue collected. This contrasts with the noncorporate exclusion policy, where other sources of revenue instead contribute to the total tax revenue shortfall. In this scenario, the avoidance-driven shift in productive activity from the corporate sector to the noncorporate sector substantially reduces corporate income tax revenue while only moderately increasing noncorporate income tax revenue. Furthermore, this insufficient offset is growing over time: While the noncorporate exclusion policy raises about 8.0% less total revenue than the benchmark policy in the first year, it raises about 20.8% less in the thirtieth year.

4.2.2 Avoidance vs. Evasion

Recent empirical studies emphasize that, in addition to legal avoidance, illegal evasion via the under-reporting of assets and/or over-reporting of liabilities is an important component of the overall household behavioral response to wealth taxation (Seim (2017), Durán-Cabré et al. (2019), and Brülhart et al. (2022)). Penn-Wharton Budget Model (2019), Penn-Wharton Budget Model (2020), and Diamond and Zodrow (2020) incorporate evasion into their macroeconomic analyses of wealth tax proposals using a simplified reduced-form approach, whereby households under-report taxable wealth according to an exogenous semi-elasticity.[31] To draw contrast with the avoidance behavior highlighted in this paper, we simulate our broad-based policy while allowing for evasion using the same reduced-form approach. This involves the respecification of equation (3.1) to:

$$\mathcal{T}_t^{\boldsymbol{w}}(h_j^o, a_j) = (1 + \varepsilon\tau^{\boldsymbol{w}})\left(\max\left(\tau^{\boldsymbol{w}}(a_j + (1-\kappa^{dur})h_j^o - \bar{y}), 0\right)\right)$$

where ε is the semi-elasticity of reported wealth with respect to the tax rate. We choose a value of $\varepsilon = -19$ for our simulations so that the 30-year average annual total tax revenue increase in this scenario is approximately the same as that from the noncorporate equity exclusion policy, i.e. a 14.8% revenue shortfall compared to the benchmark policy (See Table 4).[32] With comparable revenue losses due to evasion and avoidance due to the noncorporate equity exclusion, differences in macroeconomic aggregates can be more easily attributed to the different underlying behavioral responses.

Figure 1 shows that the reduction in the time paths for household wealth are relatively attenuated for both asset classes when wealth is systematically under-reported.[33] Under the assumption that unreported assets remain within the domestic financial system,[34]

[31] Rotberg and Steinberg (2022) allow for endogenous evasion responses that vary across households.

[32] Local perturbations to $\varepsilon = -19$ do not substantially change our results.

[33] While Brülhart et al. (2022) points out that financial assets are under-reported at a greater frequency than housing assets, we assume uniform evasion rates to maintain simplicity and consistency with previous analyses.

[34] This assumption is maintained in Penn-Wharton Budget Model (2019), Penn-Wharton Budget Model (2020), Diamond and Zodrow (2020), and Rotberg and Steinberg (2022).

there are relatively more resources available for private investment by firms than in any other scenario analyzed here. Relative to the benchmark scenario, aggregate capital and labor are therefore about 0.2% and 0.4% higher on average over three decades as shown in Figure 3. In the absence of cross-sector distortions, the response of economic activity is symmetric in both the corporate and noncorporate sectors with output above its benchmark level by 0.3% on average. Notably, this is the only alternative tax base scenario where output exceeds its pre-policy level within three decades.

Figures 4 and 5 show the time paths of wealth tax revenue and federal tax revenue from other sources. When evasion occurs at our specified intensity under a broad-based wealth tax, revenue raised directly from the wealth tax is relatively lower than the benchmark policy by $65 billion and $86 billion in the first and thirtieth years following implementation (in 2018 dollars), differentials larger than any other tax base alternative analyzed here. Because the three-decade total average annual tax revenue increase matches the same 14.8% benchmark policy shortfall as the noncorporate exclusion policy by design, we can observe a distinct difference in the pattern of the shortfall across policies: While the noncorporate exclusion policy has a growing relative shortfall over three decades, the broad-based policy with evasion has a shrinking relative shortfall, from 20.1% in the first year to 7.7% in the thirtieth year. Thus, while the revenue losses from avoidance in the noncorporate equity exclusion policy are growing over time, the losses from evasion are shrinking over time.

4.3 Alternative Budgetary Assumptions: Expenditures

For our benchmark simulation, it is assumed that additional federal tax revenue under the wealth tax is used to reduce outstanding public debt. However, this closing assumption is not innocuous. To show how the projected macroeconomic and budgetary effects of a wealth tax depend on how the additional revenues are used, we consider the following alternatives to federal debt reduction: (*i*) the creation of an annual UBI transfer, (*ii*) a permanent expansion of the federal standard deduction,[35] and (*iii*) increased investment in public infrastructure. That is, rather than allowing $B^{g,tot}_{t+1}$ to take on the residual value of the federal government's recursive budget constraint each period along the transition path, we instead allow the residual value to determine trs_t, $\mathcal{T}^i_t(i^{f,z}_{t,j}, r^p_t a_j)$, and I^{fed}_t respectively. Below we describe the macroeconomic and budgetary effects over the first three decades following enactment of the broad-based wealth tax with each alternative expenditure policy, expressed in terms relative to the benchmark debt-reduction scenario.

[35] The standard deduction is a specific dollar amount that reduces the amount of income on which a household is taxed. An expansion of the standard deduction is therefore a type of overall income tax cut. Since our model is calibrated to the 2017 economic and tax-law environment, our baseline standard deduction is equal to $6,457 and $12,915 for single and married households (expressed in 2018 dollars). This provision is modeled explicitly within our internal tax calculator.

Effect on Productive Activity: Figure 6 shows that when additional revenues are used to expand the standard deduction, an increase of 161.0% and 82.3% in the deduction amount relative to baseline are availed in the first and thirtieth years. Although the expanded deduction is inframarginal for high-income households who remain within the top statutory income tax bracket, it is an incentive to increase labor supply for other households who may be pulled into a lower statutory tax bracket. The resulting lower real wage rate shown in Figure 7 causes firms to substitute labor for capital in production. Figure 8 shows that while labor supply is about 0.7% higher on average relative the debt-reduction scenario, the capital stock is about 0.9% smaller on average. Because the latter increasingly diminishes the positive output effect over time by reducing aggregate labor productivity, aggregate output declines from its high point of 0.5% above the debt-reduction scenario in year two to 0.9% below it in year thirty.

When used for investment in public infrastructure, additional revenues under broad-based wealth tax allow for a net-of-depreciation increase in federal public capital relative to GDP of about 18.5 percentage points (from about 8.8% to 27.3%) after three decades.[36] This increase in public capital, which incorporates time-to-build effects and state-local offsets, increasingly raises the productivity of both private factors of production and increases firm demand for private capital and labor. Compared to the debt-reduction scenario on average over three decades, this allows for labor to be about 0.5% higher and private capital to be about the same despite the absence of crowding-in effects. Due to increasing public capital, aggregate output is about 1.7% higher than the debt-reduction scenario by the end of three decades.

When additional revenues are used to finance the creation of an annual UBI transfer, the broad-based wealth tax allows for transfers of \$1716 per taxpayer in the first year, falling to \$1053 per taxpayer in the thirtieth year.[37] Because these transfers have a positive income effect on all households, there is a reduction in labor supply of about 0.5% relative to the debt-reduction scenario on average over three decades. Since this reduces the marginal productivity of capital, firms also reduce capital by about 1.3% on average. This results in a relatively low path of aggregate output, which is about 1.4% below the debt-reduction scenario after three decades.

Effect on Household Wealth: Figure 9 shows that when additional revenues are used to expand the standard deduction instead of debt-reduction, the time path of aggregate housing is elevated by about 1.1% while the time path of aggregate financial assets are depressed by about 0.4%, both relative to the debt-reduction scenario on average over three decades. The expanded standard deduction creates a first-order incentive for low-

[36]Local perturbations to public capital's share of output do not substantially change our results.

[37]In computing this figure, we assume that the 144.3 million tax units who filed federal returns in 2018 grows at our assumed annual population growth factor of $\Upsilon_P = 1.0076$

and middle-income taxpayers in the 'Bottom 99%' group to increase labor supply and subsequently housing because of the consumption services it provides. This effect is absent from the 'Top 1%' wealthiest households because their income is sufficiently high that the expanded deduction does not pull them to a lower statutory tax bracket. Instead, these households experience only an income effect that causes them reduce both financial assets and housing.

When additional revenues are instead used to finance public infrastructure investment, both aggregate financial assets and housing exhibit a U-shaped time path that leaves each about 2.0% and 1.9% higher than they are under the debt-reduction scenario at the end of three decades. This occurs because the positive effect of public infrastructure on factor returns builds over time. These second-order price changes generate an increase in the portfolio rate of return that encourages households in both the 'Top 1%' and 'Bottom 99%' groups to hold relatively more financial assets, as well as positive real wage growth that leads these households to hold relatively more housing.

Finally, when additional revenues are used to create an annual UBI transfer, the time paths of aggregate financial assets and housing are about 1.2% below and 1.1% above their paths in debt-reduction scenario on average over three decades. This is primarily driven by the households in the 'Bottom 99%' group, for whom the transfers make up a relatively larger portion of income. These households experience a first-order income effect that causes them to reduce their holdings of financial assets and increase housing accumulation. This result is similar to the standard deduction expansion scenario, with the primary difference stemming from the depressing effect that the reduced labor supply has on financial asset holdings of households in the 'Bottom 99%' group.

Effect on Tax Revenue: Changes to federal income and wealth tax revenues are shown in Figures 10 and 11 for all alternative expenditure scenarios. There is a positive correlation between the rank order of long-run changes in total tax revenue and the rank order of long-run changes in aggregate output. This occurs because, out of the options analyzed here, expenditures that have relatively more positive (negative) effects on aggregate output also have relatively more positive (negative) effects on the overall federal tax base. However, the increase in federal government outlays afforded in each scenario do not follow the same rank order, as the federal debt reduction scenario violates rank preservation with the most budgetary feedback. This can be seen by expressing the additional amount of outlays made by the federal government on an average annual per-taxpayer basis:[38] about \$3,360, \$2,280, \$1,553, \$1,370 for the federal debt reduction, public infrastructure investment, standard deduction expansion, and UBI transfer scenarios respectively. The debt reduction scenario violates rank preservation in particular because budgetary feed-

[38] In computing these figures, we assume that the 144.3 million tax units who filed federal returns in 2018 grows at our assumed annual population growth factor of $\Upsilon_P = 1.0076$

back includes both changes to total tax revenue and changes to interest payments on federal debt, both of which decrease only in that scenario.[39] Because federal debt and interest on federal debt remain elevated in all of the alternative expenditure scenarios, additional budgetary resources that can be used for an expansion of expenditures are not freed as in the debt-reduction scenario.

5 Conclusion

This paper uses an overlapping generations model with endogenous avoidance and rich tax detail to show how the macroeconomic and budgetary effects of a wealth tax for the United States depend on its practical specification. We find that the provision of exclusions from the tax base for owner-occupied housing and privately-held noncorporate equity, which are common in practice due to administrative difficulty in valuation, distort investment choices and create avoidance opportunities that can undermine the revenue-raising potential of the tax. We also find that the range of possible uses for the additional revenue generated by the tax implies a range macroeconomic outcomes from contractionary to expansionary.

Our findings provide policymakers with information pertinent to the design of a wealth tax for the United States. First, if an attempt is made to levy a wealth tax on a broad base, then the costs of enforcing the broad base should be weighed against the potential revenue to be gained by eliminating avoidance. Second, the extent to which the macroeconomic effects of a wealth tax depend on how the additional revenues are used means that the optimality of a given statutory wealth tax schedule will depend on the expenditures that are paired with the tax. Thus, our findings suggest that a wealth tax regime should be viewed in a holistic fashion, with the design of the tax and the use of the revenues considered jointly.

[39] Budgetary feedback also depends on changes to endogenous outlays, such as social security payments to retirees. However, this explains only a relatively small portion of the difference in our model and takes decades to materialize.

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6 Tables and Figures

Table 1: Baseline Top Wealth Shares and Thresholds

Shares			
Wealth Group	**Data**, 2016 (Smith et al., 2022)	**Data**, 2016 (Saez and Zucman, 2020)	**Model**
Top 10%	68.4%	77.5%	66.7%
Top 1%	32.9%	38.8%	35.3%
Top 0.1%	15.9%	19.8%	19.7%
Thresholds (in thousands of 2018$)			
Wealth Group	**Data**, 2016 (Smith et al., 2022)	**Data**, 2016 (Saez and Zucman, 2020)	**Model**
Top 10%	$1,057	$931	$1,065
Top 1%	$5,626	$5,034	$4,109
Top 0.1%	$26,988	$25,120	$31,084

- Figures inflation-adjusted from 2016 using a C-CPI-U factor of 1.038.
- All figures are at the tax-unit level.
- Tax-unit level estimates of Smith et al. (2022) obtained from private correspondence.
- The Saez and Zucman (2020) estimates reflect an update to the Saez and Zucman (2016) estimates, and are maintained at https://gabriel-zucman.eu/uswealth/.

Table 2: Baseline Financial Assets Composition

% of Financial Assets	Corporate Equity	Noncorporate Equity	Fixed-Income Wealth	Rental Housing Wealth
	52.5%	29.5%	15.1%	2.9%

Table 3: Baseline Total Wealth Composition

Wealth Group	Financial Assets as % of Total Wealth
Top 10%	76.6%
Top 1%	81.5%
Top 0.1%	88.8%

Table 4: Annual Revenue Increase (in billions of 2018$)

Annual Wealth Tax Revenue Increase	Year 1	Year 15	Year 30	30-Year Average
No Exclusion (Benchmark) Policy	285	341	423	347
Housing Exclusion Policy	263	316	392	322
Noncorporate Equity Exclusion Policy	257	303	368	308
Broad-based Policy with Evasion	220	269	337	274
Annual Total Tax Revenue Increase	Year 1	Year 15	Year 30	30-Year Average
No Exclusion (Benchmark) Policy	243	271	349	284
Housing Exclusion Policy	239	259	352	278
Noncorporate Equity Exclusion Policy	225	227	289	242
Broad-based Policy with Evasion	201	229	324	242

Figure 1: Wealth Tax Base Alternatives: Household Wealth

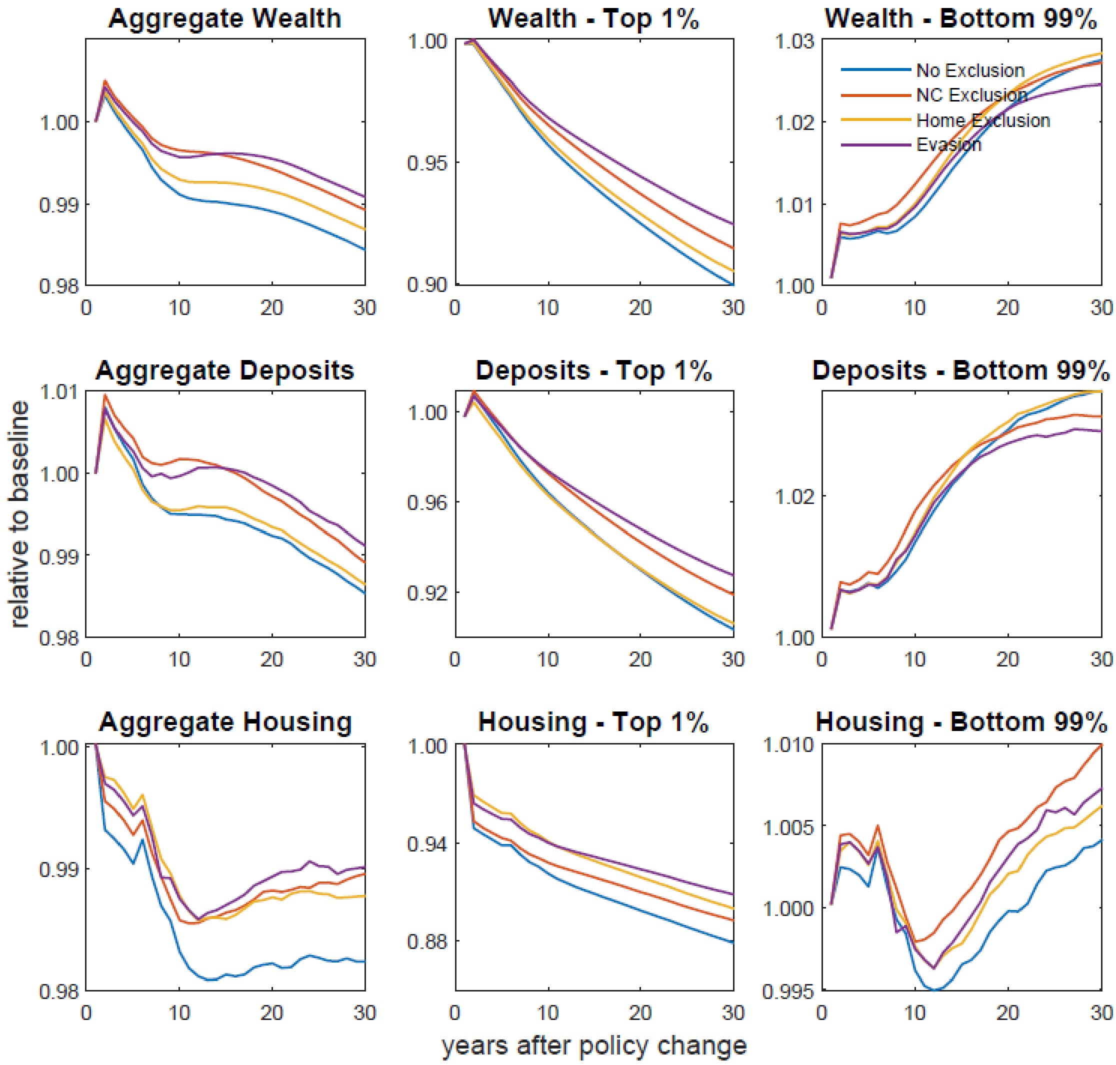


Figure 2: Wealth Tax Base Alternatives: Prices

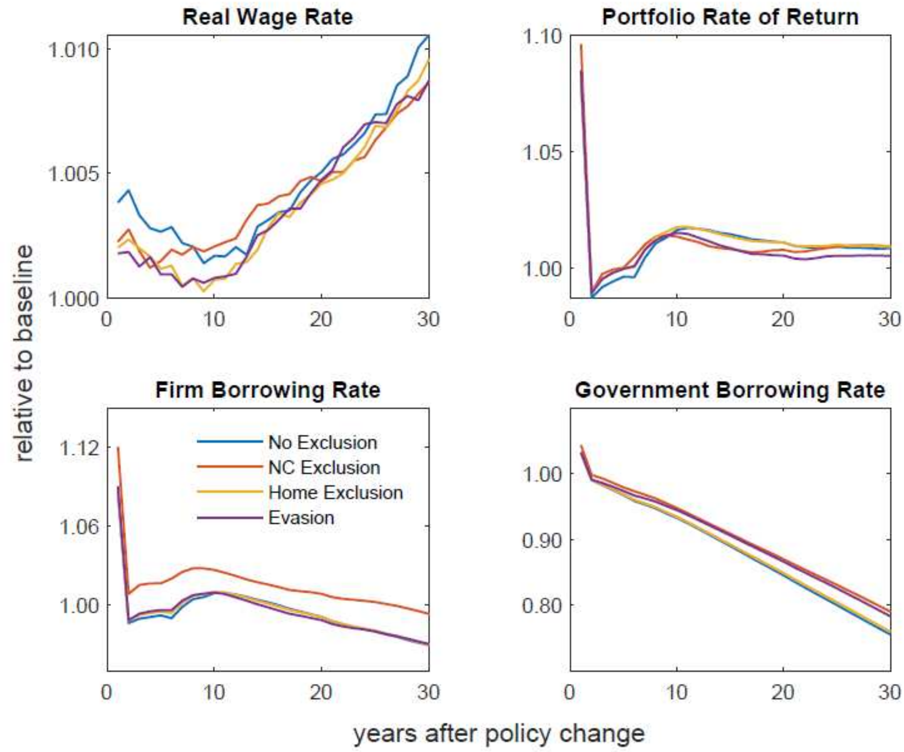


Figure 3: Wealth Tax Base Alternatives: Productive Activity by Sector

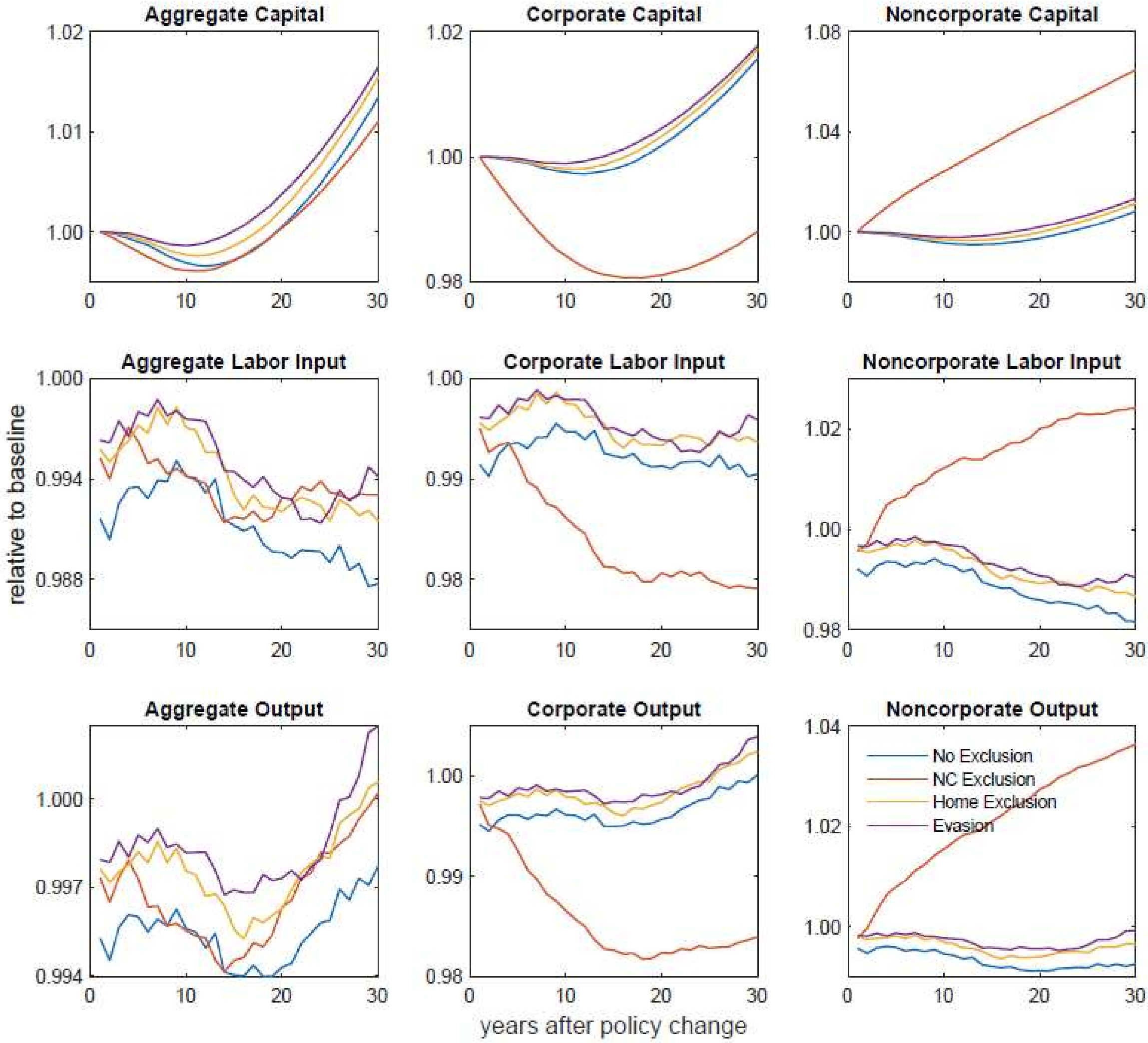


Figure 4: Wealth Tax Base Alternatives: Wealth Tax Revenue

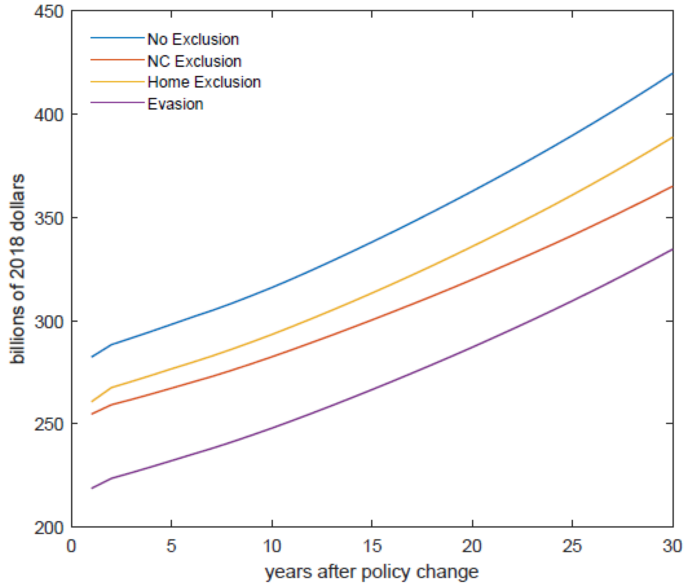
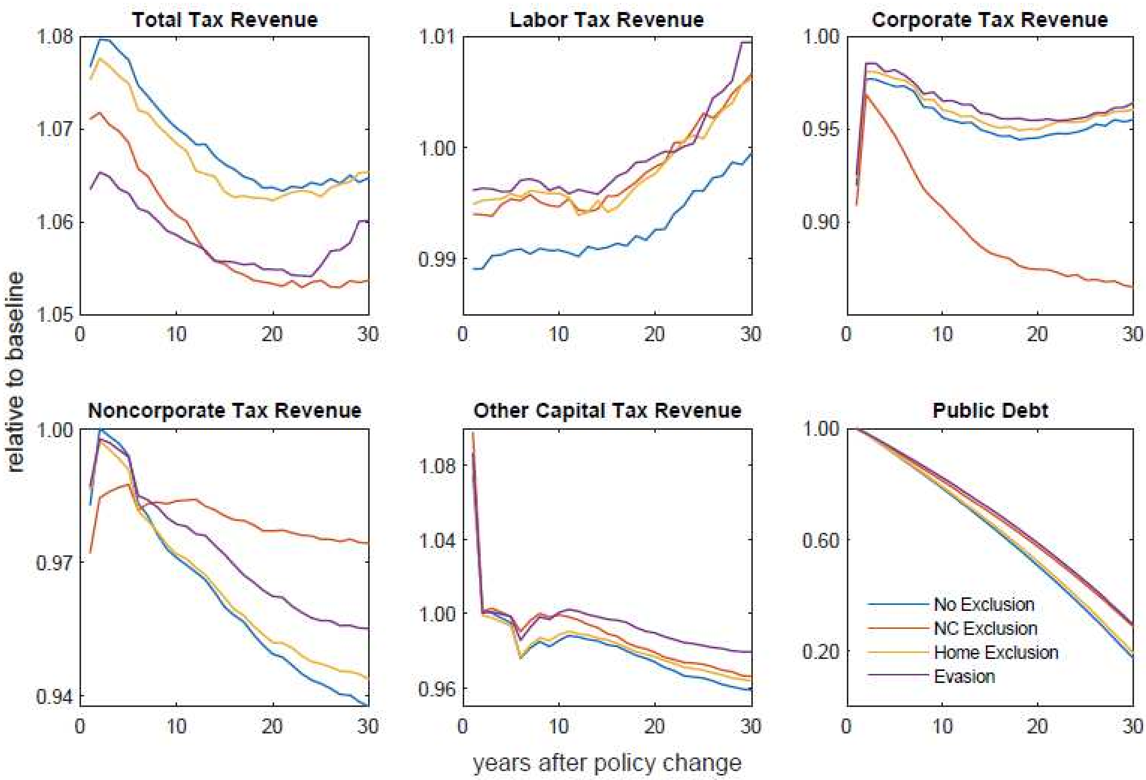


Figure 5: Wealth Tax Base Alternatives: Federal Income Tax Revenue Sources and Debt



Note: 'Labor Tax Revenue' includes revenue from payroll taxes in addition to income taxes on wages and Social Security benefits. 'Other Capital Income Tax Revenue' includes revenue from the taxation of dividends, interest, capital gains, and estates.

Figure 6: Expenditure Alternatives

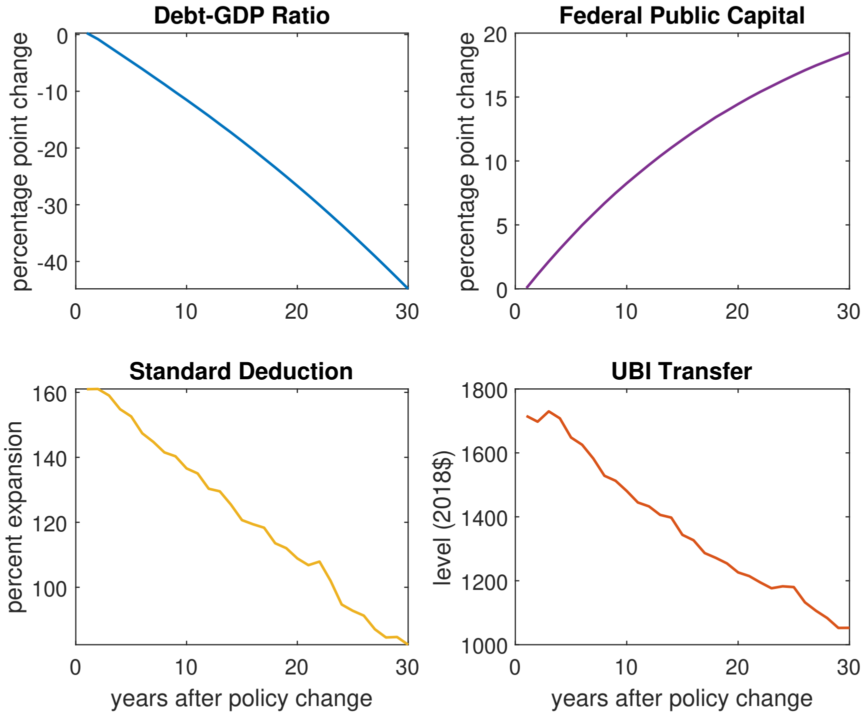


Figure 7: Expenditure Alternatives: Prices

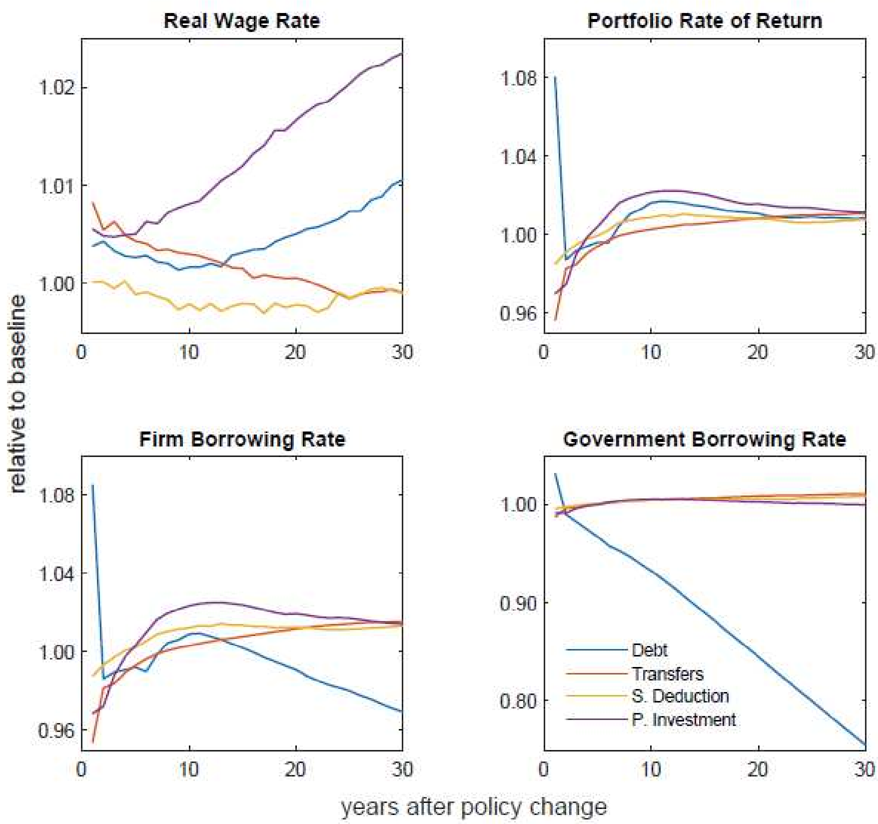


Figure 8: Expenditure Alternatives: Aggregates

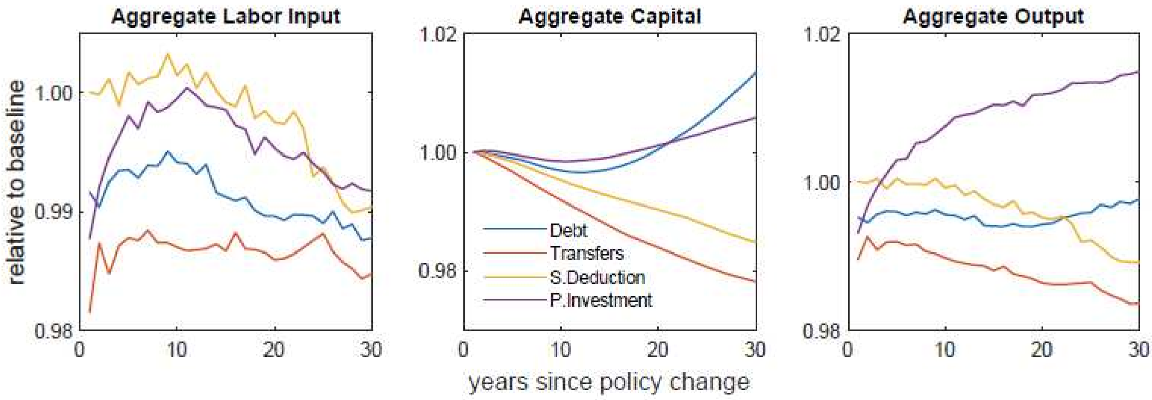


Figure 9: Expenditure Alternatives: Household Wealth and Labor Supply

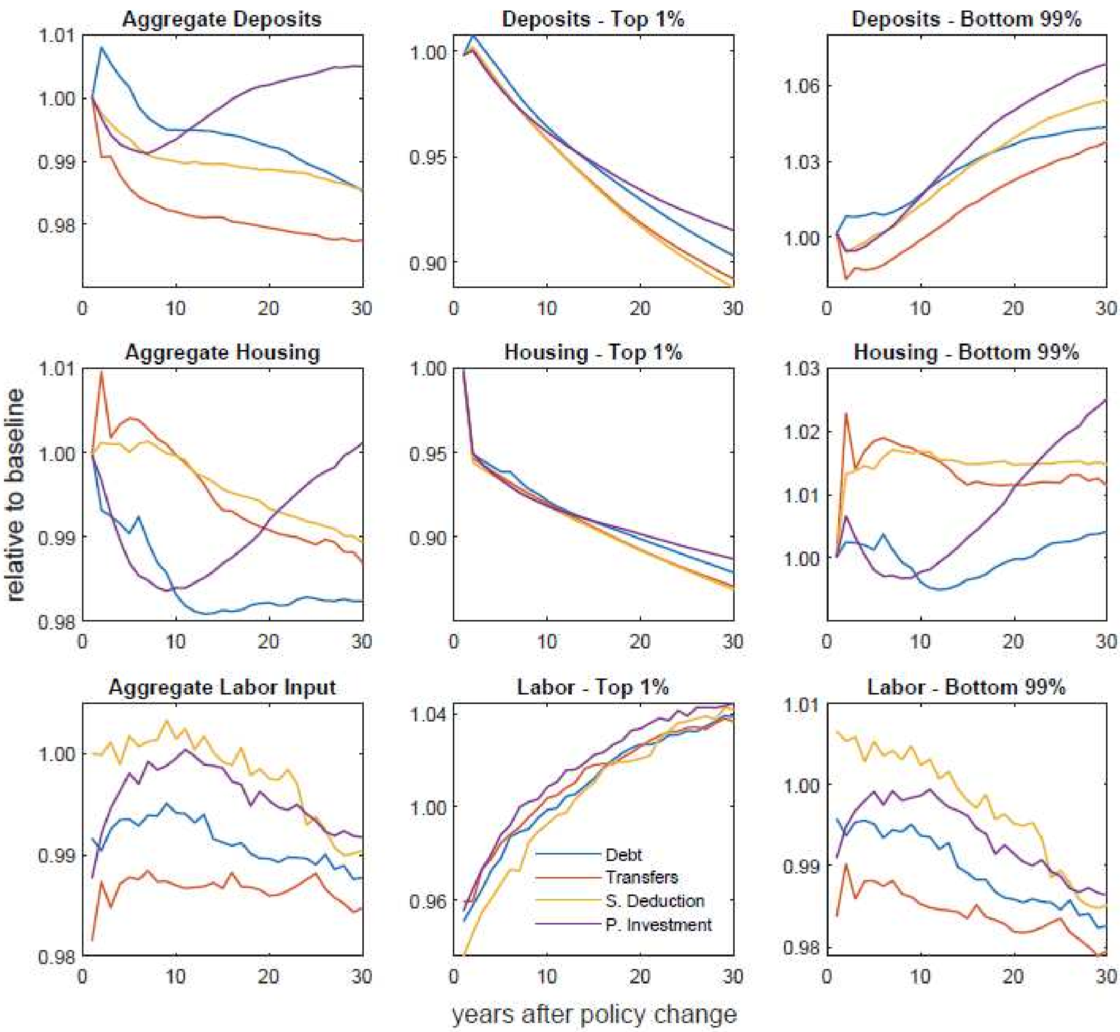


Figure 10: Expenditure Alternatives: Wealth Tax Revenue

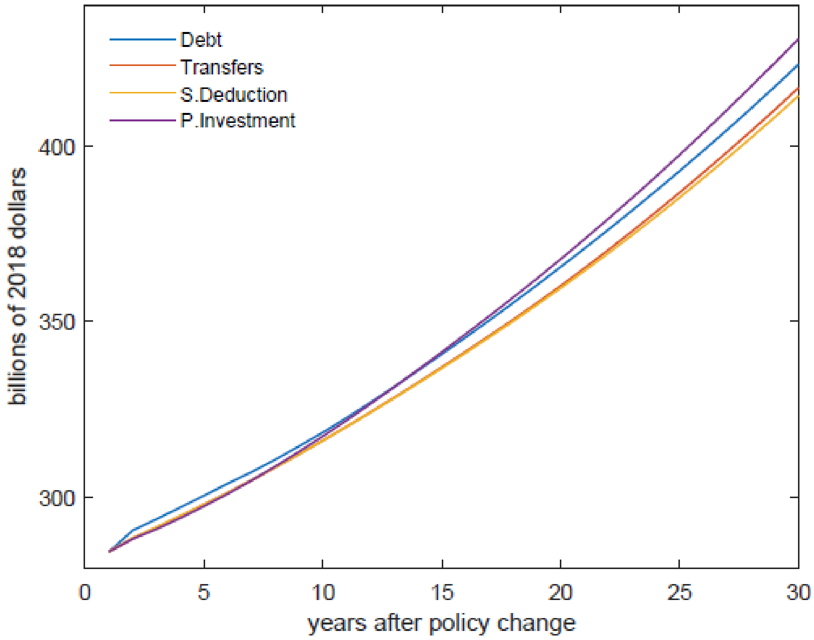
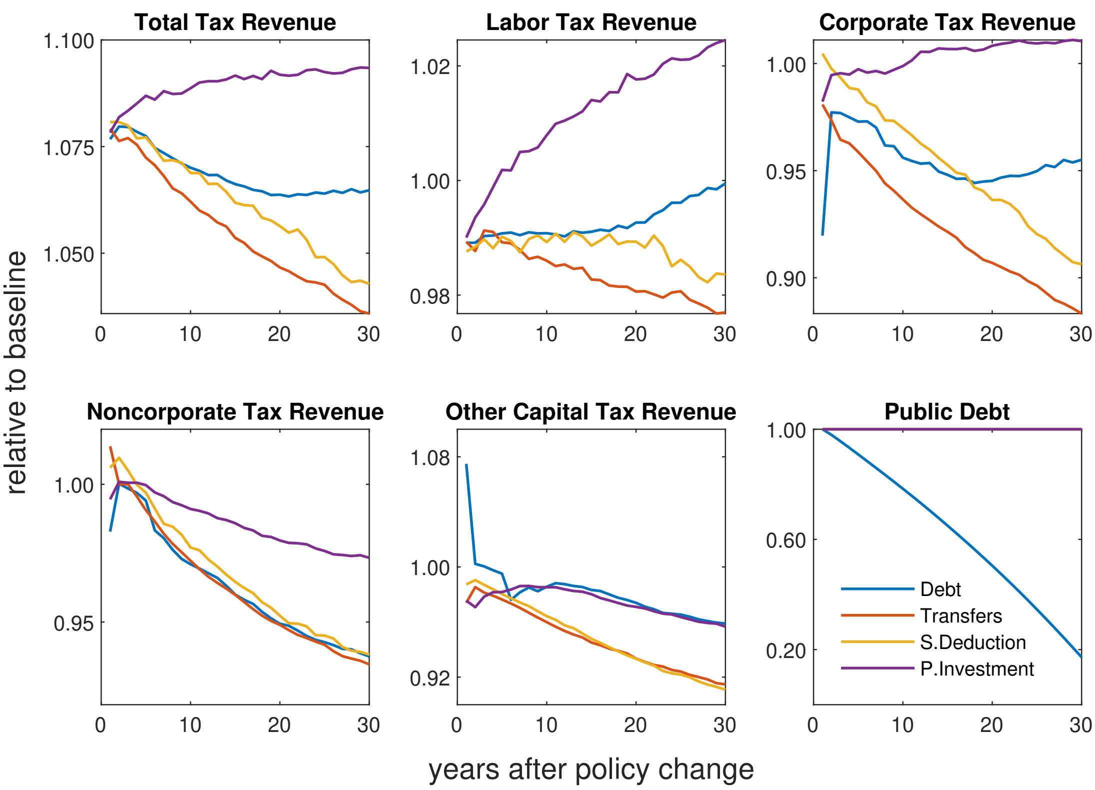


Figure 11: Expenditure Alternatives: Federal Income Tax Revenue Sources and Debt



Note: (i) 'Labor Tax Revenue' includes revenue from payroll taxes in addition to income taxes on wages and Social Security benefits. 'Other Capital Income Tax Revenue' includes revenue from the taxation of dividends, interest, capital gains, and estates. (ii) The federal income tax revenue loss from the expansion of the standard deduction is added back to each source for purposes of this figure.

Appendices for Online Publication

A Nested Consumption Detail in Households' Problem

As described in Section 2.1, the consumption-composite good x_j enters the households' budget constraint valued at the implicit price p_t^x. So that we can incorporate consumption of tax-preferred goods within our framework, the composite good is an endogenous consumption bundle of market goods, housing services, home-produced goods, and charitable giving. In this section, we describe how each sub-component is nested in x_j, and how a numerical solution to the household's problem is obtained.

Nested directly within x_j in a CES fashion are non-housing consumption c_j and housing service consumption hs_j:

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

For housing service consumption, we assume that a unit of owner-occupied housing h_j^o and rental housing h_j^r provide equivalent durable housing services from which utility is derived. Further, since we restrict a household's residential status to a binary choice of renting or owning, preferences take the form:

$$hs_j \equiv \max\{h_j^o, h_j^r\} \tag{A.2}$$

For non-housing consumption, we assume c_j is itself a Cobb-Douglas composite of different non-durable consumption types. The first sub-component is 'warm-glow' (Andreoni, 1989) charitable giving, c_j^g, which is assumed to be made in terms of final goods and received by agents outside of the model. The second sub-component, c_j^i, is the sum of market-produced consumption c_j^M and home-produced consumption services $c_j^{f,H}$:

$$c_j \equiv (c_j^i)^{\theta^{f,z}} (c_j^g)^{(1-\theta^{f,z})} \tag{A.3}$$

$$c_j^i \equiv \begin{cases} c_j^M + c_j^{s,H}(\bar{n}_j) & \text{if} f = s \\ c_j^M + c_j^{m,H}(\bar{n}_j^1, \bar{n}_j^2) & \text{if} f = m \end{cases} \tag{A.4}$$

where home-produced consumption services are assumed to be an exogenously decreasing, time-invariant function of the market labor hours supplied by each adult in the household. Substitution of market-produced for home-produced consumption services is thus limited by time use.[1]

[1]This simple structure of home production is included because it helps to replicate the heterogeneity in market hours across demographics at older ages as documented by Kuhn and Lozano (2008). Because

With the above consumption detail, we can express a given household's budget constraint at the disaggregated level as follows:

$$c_j^M+c_j^g+p_t^r h_j^r+a_{j+1}+h_{j+1}^o = (1+r_t^p)a_j+(1-\delta^o)h_j^o+i_{t,j}^{f,z}+inht,j^{f,z}-\mathcal{T}_{t,j}^{f,z}-\kappa_j^{f,z}-\xi_j^H \quad \text{(A.5)}$$

where market consumption and charitable giving are in terms of the numéraire, and p_t^r is the relative price of rental housing. The above budget constraint (A.5) is equivalent to budget constraint (2.6) when the nested choice variables $\{c_j^M, c_j^g, h_j^o, h_j^r\}$ are evaluated are their optimal levels.

We approach the solution to this problem as follows: First, we employ a change of variables to reduce the state space from (a_j, h_j^o) to (y_j). Using the definition of net worth, $y_j \equiv a_j + h_j^o$, budget constraint (A.5) can be expressed as:

$$c_j^M + c_j^g + p_t^r h_j^r + (r_t^p + \delta^o)h_j^o + y_{j+1} = (1 + r_t^p)y_j + i_{t,j}^{f,z} + inh_{t,j}^{f,z} - \mathcal{T}_{t,j}^{f,z} - \kappa_j^{f,z} - \xi_j^H \quad \text{(A.6)}$$

Next, we discretize the state-space over current and future net worth so that analytical solutions for each choice variable can be expressed in terms of some combination of (y_j, y_{j+1}), discrete labor nodes $n_j \in \mathbb{N}$, and the binary residential status. Maximizing the objective functions (A.1) and (A.3) subject to (A.2), (A.4), and (A.6), yields the following analytical interior solutions for $\{c_j^{M*}, c_j^{g*}, h_j^{o*}\}$ when $hs_j = h_j^o$ and $\{c_j^{M*}, c_j^{g*}, h_j^{r*}\}$ when $hs_j = h_j^r$:

$$c_j^{M*} = \left(\left(\vartheta_{t,j}^{f,z}\right)^{(\theta^{f,z}-1)} \varphi_{t,j}^{f,z}\Phi_{t,j}^{f,z}\right) x_j - c_j^{f,H} \quad \text{(A.7)}$$

$$c_j^{g*} = \left(\left(\vartheta_{t,j}^{f,z}\right)^{\theta^{f,z}} \varphi_{t,j}^{f,z}\Phi_{t,j}^{f,z}\right) x_j \quad \text{(A.8)}$$

$$h_j^{o*} = \left(\Phi_{t,j}^{f,z}\right) x_j \qquad \text{if} \;\; hs_j = h_j^o,\; h_j^r = 0 \quad \text{(A.9)}$$

$$h_j^{r*} = \left(\Phi_{t,j}^{f,z}\right) x_j \qquad \text{if} \;\; hs_j = h_j^r,\; h_j^o = 0 \quad \text{(A.10)}$$

where:

variance in market labor productivity grows as households age while home productivity remains constant, the net benefit of time use for market labor grows by relatively more for higher productivity households of a given age.

$$p_t^x = \begin{cases} \Phi_{t,j}^{f,z}\left(\varphi_{t,j}^{f,z}\left((\vartheta_{t,j}^{f,z})^{(\theta^{f,z}-1)} + (\vartheta_{t,j}^{f,z})^{(\theta^{f,z})}\right) + r_t^p + \delta^o\right) - (c_j^{f,H}/x_j) & \text{if } \ hs_j = h_j^o, \ h_j^r = 0 \\ \Phi_{t,j}^{f,z}\left(\varphi_{t,j}^{f,z}\left((\vartheta_{t,j}^{f,z})^{(\theta^{f,z}-1)} + (\vartheta_{t,j}^{f,z})^{(\theta^{f,z})}\right) + p_t^r\right) - (c_j^{f,H}/x_j) & \text{if } \ hs_j = h_j^r, \ h_j^o = 0 \end{cases} \tag{A.11}$$

$$\Phi_{t,j}^{f,z} = \left(\sigma\left(\varphi_{t,j}^{f,z}\right)^{\eta} + (1-\sigma)\right)^{-1/\eta} \tag{A.12}$$

$$\varphi_{t,j}^{f,z} = \begin{cases} \left(\left(\dfrac{1-\sigma}{\sigma}\right)\left(\dfrac{\left((\vartheta_{t,j}^{f,z})^{(\theta^{f,z}-1)} + (\vartheta_{t,j}^{f,z})^{(\theta^{f,z})}\right)}{r_t^p + \delta^o + \partial\mathcal{T}_{t,j}^{f,z}/\partial h_j^o}\right)\right)^{1/(\eta-1)} & \text{if } \ hs_j = h_j^o, \ h_j^r = 0 \\ \left(\left(\dfrac{1-\sigma}{\sigma}\right)\left(\dfrac{\left((\vartheta_{t,j}^{f,z})^{(\theta^{f,z}-1)} + (\vartheta_{t,j}^{f,z})^{(\theta^{f,z})}\right)}{p_t^r}\right)\right)^{1/(\eta-1)} & \text{if } \ hs_j = h_j^r, \ h_j^o = 0 \end{cases} \tag{A.13}$$

$$\vartheta_{t,j}^{f,z} = \left(\frac{1-\theta^{f,z}}{\theta^{f,z}}\right)\left(\frac{1 + \partial\mathcal{T}_{t,j}^{f,z}/\partial c_j^M}{1 + \partial\mathcal{T}_{t,j}^{f,z}/\partial c_j^g}\right) \tag{A.14}$$

Note that this nesting structure does not impose additional restrictions on the household's problem described in Section 2.1, as the original budget constraint (2.6) can be recovered by substituting the optimal choices (A.7)-(A.10) and the expression (A.11) for the implicit price p_t^x into the dissaggregated budget constraint (A.5).

The optimal sequence of choices for a given household of demographic (f, z), which is the solution to the household problem described in Section 2.1 with the nesting structure described in this section, is obtained by backwards induction. Iterating backwards from the terminal age J, candidates for interior solutions of all endogenous variables across each set of adjacent periods $(j, j+1)$ are obtained using the modified endogenous grid method of Iskhakov et al. (2017) over the reduced state space (y_j, y_{j+1}), and for all possible combinations of $n_j \in \mathbb{N}$ and the binary residential status. Candidates for corner solutions are obtained using brute force over the same dimensions. The set of optimal choices, which maximize value function $V_{t,j}^{f,z}(y_j)$, are obtained from the candidate solutions at each grid point over a common current net worth grid.

B Calibration

In this section, we describe our calibration strategy for non-tax parameters in the initial steady state baseline. Select exogenous parameters are summarized in Table A1.

B.1 Households

B.1.1 Demographics

The population is assumed to grow exogenously at the gross average annual rate of $\Upsilon_P = 1.0076$ computed for the United States over years 2017-2027 from the Census Bureau. Households entering the economy at model age $j = 1$, (actual age 25), and can live for a maximum of $J = 76$ (actual age 100). Over their lifecycle individuals in households may choose to work for their first $R - 1 = 40$ model years, over which time they are assumed to survive with certainty so that their conditional survival probability is $\pi_j = 1$ for $j = 1, ..., R - 1$. All individuals must be retired by model age $j = R$ (actual age 66), at which time they face mortality risk so that $\pi_j < 1$ for $j = R, ..., J$ with $\pi_J = 0$. The conditional survival probabilities corresponding to ages 41 through 89 are computed from the Social Security Administration's *2013 Actuarial Life Table* as a weighted average of males and females.

The stationary age profile of households is computed to account for population growth and mortality risk such that $\Omega_{t,j+1} = (\Omega_{t,j}\pi_j)/\Upsilon_P$, and is normalized to a unit measure $\sum_{j=1}^{J} \Omega_j = 1$. The family composition-age profile $\Omega^f_{t,j}$ is computed for $f = s, m$ as the share of non-joint and joint tax filing units respectively out of total tax units using the ITM. Letting $\Omega^z_{t,j}$ be the population share of each labor productivity type, we compute the measure of households as $\Omega^{f,z}_{t,j} = \Omega^f_{t,j}\Omega^z_{t,j}\Omega_{t,j}$.

B.1.2 Labor Characteristics

We define economic labor income in the model to be a NIPA-comparable wage income concept plus self-employment income.[2] Letting each productivity type $z = 1, ..., 8$ correspond to the notion of a lifetime labor income class for each family composition type $f = s, m$, we use the ITM to distribute the cross-sectional labor income of non-dependent tax filers with age of primary between 25-64.[3] Each for non-joint and joint tax filers, the $nz = 8$ productivity types represent the following percentile classes: $\{0 - 20; 21 - 40; 41 - 60; 61 - 80; 81 - 90; 91 - 99; 99 - 99.9; 99.9 - 100\}$.

[2] The 'NIPA-comparable' measure used here is the sum of (*i*) AGI wage income (*ii*) combat pay, (*iii*) employers' share of the FICA tax, (*iv*) deferred 401k compensation, (*v*) employers share of 401k compensation, (*vi*) employer provided dependent care, (*vii*) employer health-insurance compensation, (*viii*) employer HSA compensation, and (*ix*) employer life-insurance compensation.

[3] The BEA does not report distributional characteristics of NIPA wage income the same income classes levels used in our model.

Labor productivity for each (z, f, j) demographic, $\mathrm{z}_j^{z,f}$, is the product of a demographic-independent age-varying component, z_j, and a demographic-dependent age-invariant component, $\mathrm{z}^{z,f}$. The age-varying component is exogenously set to the smoothed wage profiles estimated by Rupert and Zanella (2015) for all individuals. The age-invariant component is calibrated internally for each (z, f) demographic so that average annual labor income over working ages $j = 1, .., R-1$ in the initial steady state matches average annual labor income target, $\bar{i}^{f,z}$, computed for their respective percentile class from the ITM. While both individuals in married households face the same productivity term $\mathrm{z}_j^{z,m}$, there is an exogenous productivity wedge μ^z between primary and secondary workers. We compute this wedge as the relative hourly earnings of secondary workers from the 2015 Medical Expenditures Panel Survey for each income quintile of married couples.[4]

The individual labor supply choice set has three discrete employment options — unemployment, part-time, and full-time — with each option corresponding inversely to time spent on home production. Using the 2017 American Time Use Survey from the U.S. Bureau of Labor Statistics, we compute the average hours that an employed individual spends working in full-time and part-time jobs respectively, and the 2013-2017 average for hours spent on 'household activities' for unemployed, part-time, and full-time single, married primary, and married secondary individuals respectively. Assuming that individuals in the model sleep on average 8.8 hours per day, we map normalized waking-time spent on market work to home production as follows:

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

Monetary child-care costs, $\kappa_j^{z,f}$, depend on a household's number of dependents $\nu_j^{f,z}$ and the market work hours of the single or married secondary adult so that:

$$\kappa_j^{z,f} \equiv \begin{cases} cc^{z,s}\nu_j^{z,s}n_j & \text{if } f = s \\ cc^{z,m}\nu_j^{z,m}n_j^2 & \text{if } f = m \end{cases} \tag{B.1}$$

where $cc^{z,f}$ is a scale parameter. We exogenously set $\nu_j^{f,z}$ to the average number of dependents under the age of 6 for a given (f, z, j) demographic, which are calculated using the JCT-ITM for 2017. Given the distribution of dependents, we then set the scale parameter so that childcare expenses on average for each (z, f) demographic match those values imputed by the ITM for 2017 when labor supply is evaluated as the employment targets in Table A2.

[4] While the Medical Expenditures Panel Survey may seem like an odd choice, it is a large-scale survey that contains direct responses for hourly earnings of both individuals in a married couple.

The time-use term for child-rearing, $\varphi_j^{f,z}$, enters the market-labor sub-utility function for single and married-secondary adults. We set $\varphi_j^{f,z} = 0.094\nu_j^{f,z}$ 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. (2012).

B.1.3 Preferences

We use two preference parameters — households' subjective discount factor, β, and the wealth-in-utility (WIU) parameter, o_t — in targeting the estimated values of aggregate household wealth and top wealth shares.[5] First, we set $\beta = 0.940$ to target an aggregate wealth to income ratio of 5.05 within the model.[6] Second, assuming that o_t grows at the gross rate of technological progress, we set $o_t/A_t = 350$ to target a top-1% wealth concentration target of 0.359, which is the midpoint between the values estimated by Smith et al. (2022) and Saez and Zucman (2020). Characteristics of our model's wealth distribution are summarized in Table 1.

The variable labor disutility coefficients $\{\psi^s, \psi^{m,1}, \psi^{m,2}\}$ and the fixed labor disutility parameters $\{\phi^s, \phi^m\}$ are calibrated internally to target the distribution of employment statuses across earner types observed in the Medical Expenditures Panel Survey for 2015,[7] the fit of which is reported in Table A2. The values for the labor disutility curvature parameters are exogenously set to the relatively high values of $\zeta^s = \zeta^{m,1} = \zeta^{m,2} = 5$, which implies that fluctuations to aggregate employment will depend relatively more heavily on changes to duration of working life than changes to hours worked while employed (Keane and Rogerson, 2012). Furthermore, in our specification of indivisible labor supply, these curvature parameters are largely independent of the underlying Frisch labor supply elasticities, which are endogenous and can differ across worker types despite the same curvature parameter values (Chang et al., 2011).[8]

The curvature parameter for the consumption-composite good x_j is exogenously set to $\eta = -1.0534$, which implies an elasticity of substitution for housing and non-housing consumption of 0.487 (Li et al., 2016). The non-housing consumption preference parameter σ is then calibrated internally to target the ratio of private business investment to

[5]To be consistent with our targets, we exclude the implicit portion of housing wealth in our model that represents consumer durables when these computing figures. We approximate consumer durables as 28.3% of housing assets in our model, which is the average share of consumer durables in the stock of residential capital over 2007-2016 as measured by the Bureau of Economic Analysis (BEA).

[6]The numerator of this target is based on a value for aggregate household wealth in 2016 of $80.90 trillion from Smith et al. (2022), which is their 'spec #9' less their estimated value of unfunded pensions. The denomimator of this target is BEA's estimated value for 2016 national income of $16.03 trillion.

[7]We use the Medical Expenditures Panel Survey because market work hours are reported for both individuals in a married couple, and therefore allows for us to avoid erroneously using gender as a proxy for primary or secondary earners. We consider full-time work to correspond with hours greater than or equal to 35 per week, and part-time work to correspond with positive hours less than 35 per week.

[8]In a similar indivisible labor choice framework, Chang and Kim (2006) show that the aggregate labor elasticity is determined endogenously by the distribution of reservation wages, rather than by exogenous parameters.

total private investment of 0.465 as calculated from the NIPA for 2016.

In calibrating the share parameter for the non-housing consumption composite, $\theta^{f,z}$, we make use of the optimality condition for the consumption ratio c_j^g / c_j^i:

$$\frac{c_j^g}{c_j^i} = \left(\frac{1 - \theta^{z,f}}{\theta^{z,f}} \right)$$

which holds under the assumption that the marginal tax rates on consumption is zero. Let $\left(\sum_{j=1}^{R-1} c_j^{g;\bar{f},z} / \sum_{j=1}^{R-1} \bar{i}_j^{f,z} \right)$ denote an exogenous average charitable giving to labor income ratio in 2017 for working-age households computed using the JCT-ITM. Re-arranging the above optimality condition for $\theta^{f,z}$ and averaging over ages $j = 1, .., R$ yields:

$$\theta^{f,z} = \left(1 + \left(\frac{\sum_{j=1}^{R-1} c_j^{g;\bar{f},z}}{\sum_{j=1}^{R-1} \bar{i}_j^{f,z}} \right) \frac{\sum_{j=1}^{R-1} i_j^{f,z}}{\sum_{j=1}^{R-1} c_j^{i;f,z}} \right)^{-1}$$

where the target ratio is substituted in place of the model-produced ratio. Internally calibrating the share parameter in this fashion allows the model to reproduce the target charitable giving to labor income ratio, and an implied non-charitable consumption to labor income ratio.

To impute the quantity of home-produced consumption services generated by a given amount of home-production labor hours, we follow (Bridgman, 2016) and assume a consumption value equal to the wages that would be paid to a low-income worker for those hours. In terms of our model, we specify:

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

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

B.1.4 Estates

The estate of a household who dies at the end of age $\underline{j}$ is assumed to be apportioned among exogenous and age-variant end-of-life expenditures, $c_{\underline{j}}^E$, estate tax liabilities, $\mathcal{T}_t^{\boldsymbol{est}}(y_{\underline{j}+1})$,[9] and bequests, $beq_{\underline{j}}$, to descendants prior to the start of the next period. For a decedent household, this can be expressed as:

$$c_{\underline{j}}^E + \mathcal{T}_t^{\boldsymbol{est}}(y_{\underline{j}+1}) + beq_{\underline{j}} = y_{\underline{j}+1} \tag{B.2}$$

End-of-life expenditures in the period of death are assumed to consist of two components — health expenditures and charitable giving —both of which are modeled in a reduced-form fashion. For end-of-life health expenditures, we make use of the age -

[9]The specification of estate tax liabilities is discussed in Appendix B.4.1

permanent income profiles for out-of-pocket medical expenditures in the year of death estimated by De Nardi et al. (2021).[10] We double these year-of-death figures to better capture the decummulation of wealth that occurs due to out-of-pocket medical expenditures near the end of life.[11] For end-of-life charitable giving, we assume that the size of gifts made to agents outside of the model are a piecewise linear function of estate size. This function is exogenously calibrated to SOI data for 2001 as a mapping from gross estate size in millions of 2018 dollars to charitable contributions as a share of gross estate:

$$\{1.139, 2.380, 5.100, 10.200, 20.401\} \rightarrow \{0.025, 0.047, 0.059, 0.078, 0.100\}$$

Bequests made to descendants are assumed to consist of two components — endowments to households in their first year of life $j = 1$ and inheritances to all working-age households. Endowments are distributed in an exogenous, time-invariant fashion to target the distribution of wealth for young households as detailed in Appendix B.1.5. The total amount of resources available to be transferred to all working-age households as inheritances is determined as a residual from equation (B.2) less endowments. These resources are aggregated and redistributed *within* each productivity type but *across* marital status and household age in two steps: First, the total amount of bequests left by decedent households of given productivity type is allocated so that married households receive larger inheritances than single households by a factor of $\sqrt{2}$.[12] Second, the aggregate amount of inheritances for each (f, z) demographic group is then distributed across working ages based on the lifecycle profile for inheritance receipts estimated by Penn-Wharton Budget Model (2021).[13]

B.1.5 Endowments

Households enter the economy at age $j = 1$ with endowments of initial financial assets $\bar{a}_1^e$, where the endowment index $e = \{1, \ldots, ne\} \in \mathbb{E}$ is now made explicit. To derive the exogenous distribution of endowments across (f, z) demographics, we compute the mean and standard deviation of each net worth[14] class for 24-26 year old single and married

[10] Figure 6a of De Nardi et al. (2021) shows mean out-of-pocket medical expenditures age - permanent income profiles for single households. An alternate specification of these profiles for *year-of-death* expenditures of single households were obtained from the authors via private correspondence. Because both adult members of married households in our model die contemporaneously, their profiles obtained from doubling the expenditures of the single households at each each and permanent income group.

[11] Jones et al. (2021) show that for the final six years of life, nearly all out-of-pocket medical expenditures occur in the final two years.

[12] This specification reflects equivalence scaling for adults within each household.

[13] Penn-Wharton Budget Model (2021) estimates the probability of receiving an inheritance by age and income group (Table 3). We marginalize their income dimension and normalize the probabilities to unity to construct a piecewise linear lifecycle profile for working-age households in our model.

[14] The financial component of net worth is 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

individuals respectively from a truncated sample of the 1989-2016 waves of the *Survey of Consumer Finances*.[15] We obtain the following mean and standard deviations for single and married household in net worth percentile classes of $\{0-20;\ 21-40;\ 41-60;\ 61-80;\ 81-90;\ 91-99;\ 99-99.9;\ 99.9-100\}$:

$$\bar{x}^s = \{-2,304;\ 1,677;\ 8,409;\ 25,800;\ 67,330;\ 211,920;\ 861,207;\ 7,591,840\}$$
$$\bar{x}^m = \{2,169;\ 8,702;\ 20,449;\ 48,789;\ 110,283;\ 289,544;\ 888,472;\ 3,007,143\}$$

$$s^s = \{1,537;\ 1,198;\ 2,839;\ 9,209;\ 14,204;\ 98,201;\ 409,003;\ 3,088,560\}$$
$$s^m = \{1,597;\ 2,352;\ 5,110;\ 12,696;\ 24,668;\ 117,580;\ 396,588;\ 1,020,090\}$$

For each net worth percentile class and marital status combination, we draw $ne = 10$ pseudorandom numbers from standard normal distribution with the associated mean and standard deviations for each class-status combination. The distribution of initial endowments for each (f, z) demographic is then obtained from an inverse hyperbolic sine transformation to these draws.

B.2 Firms and Housing

We calibrate the production shares for private capital, α, and public capital, g, to satisfy two conditions:

$$1 - \alpha - g = 0.569$$
$$\left(\frac{g \times 1.566}{\alpha \times 0.808}\right) = 0.431$$

The first condition implies that labor's share of output will be equal to 0.569, which is the value estimated by Penn World Tables (Feenstra et al., 2015) for 2017. The second condition implies that the relative marginal productivity of public capital to private capital will be 0.431, given targets for the output to non-residential public capital ratio and output to non-residential private capital ratio of 1.566 and 0.808 as reported by NIPA for years 2007-2016 on average.[16] These conditions are satisfied with $\alpha = 0.353$

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 misc. loans).

[15] We truncate the sample by disregarding all observations in the bottom 20% and top 0.1% 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 0.1% of the distribution requires that the net worth grid be impractically large, generating untenable curse of dimensionality issues.

[16] The target of 0.431 for the relative marginal productivity of public capital to private capital is

and $g = 0.078$, the latter of which is at the lower end of the ranges preferred by Ramey (2020) and Bom and Ligthart (2014).

Since the aggregate laws of motion for all forms of capital in our model follow the same structure (ignoring time to build assumptions about public capital), rates of economic depreciation δ^κ for $\kappa = K, G, o, r$ are computed to satisfy the same steady state expression for the aggregate investment to capital ratio, $\iota^\kappa = (\Upsilon_A\Upsilon_P - 1 + \delta^\kappa)$. Using the average annual investment flows and stocks of private and public non-residential fixed assets as reported by NIPA for years 2007-2016 yields $\delta^K = 0.0799$ and $\delta^G = 0.0317$. Using the average annual investment flows and stocks of private residential fixed assets and consumer durables as reported by NIPA over the same period, we obtain $\delta^o = 0.0662$ for owner-occupied fixed assets and $\delta^r = 0.1230$ for tenant-occupied fixed assets.

We assume that firms face adjustment costs when they deviate from the steady state investment-capital ratio. Adjustment costs are assumed to be convex cost and given by the function:

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

Given the rates of population growth technological progress and economic depreciation, this adjustment cost function is parameterized by ξ^K, which for purposes of the simulations is set to 6.

We target the relative size of output produced by the corporate and noncorporate sector by making use of time-invariant scale parameters Z^q for $q = c, n$ on the firms' production functions. We set $Z^c = 1.045$ and $Z^n = 1$ to target the ratio of corporate gross receipts to total business gross receipts equal to 0.692 as computed from the SOI for 2016. Corporate and noncorporate representative firms are assumed to maintain constant debt to capital ratios of $\varkappa^{b,c} = 0.315$ and $\varkappa^{b,n} = 0.055$, which target sector-specific interest expense to aggregate output ratios of 0.039 and 0.003 as computed from the SOI and NIPA for 2016. In addition, the corporate firm distributes dividends to households as a $\varkappa^d$ portion of after-tax earnings. We set this parameter to $\varkappa^d = 0.130$, which targets the ratio of net dividends of domestic C-corporations to aggregate output of 0.031 as measured by NIPA for 2016.

Following Gervais (2002), Fernánez-Villaverde and Krueger (2010), and Cho and Francis (2011), we set the minimum owner-occupied housing equity to $\gamma = 0.20$.[17] Furthermore, we assume that there is a lower bound on the support of owner-occupied housing $\underline{\mathrm{h}}^o$. We calibrate this value internally to target a homeownership ratio of 0.637 as reported for 2015 by the *American Housing Survey.*

based on the methodology of Congressional Budget Office (2016), but adjusted here for the exclusion of residential capital.

[17]This closely corresponds to the median loan-to-value ratio of 77% for owner-occupied housing units manufactured between 2010-2015 as reported in the Census Bureau's 2015 *American Housing Survey.*

We assume that housing transaction costs take the form:

$$\xi_j^H = \begin{cases} \phi^o h_{j+1}^o & \text{if } h_j^o = 0 \\ \phi^r h_{j+1}^r & \text{if } h_j^o > 0 \end{cases} \tag{B.3}$$

where h_{j+1}^r is the quantity of housing rental by a household.[18] Following Gruber and Martin (2003), we assume symmetric transaction costs and set $\phi^o = \phi^r = 0.05$.

Both homeowners and renters can borrow and accumulate debt in excess of assets subject to the borrowing constraint in Equation (2.8). While homeowners can use their property as collateral so long as they maintain their minimum housing equity share of γ, renters cannot have negative net worth in excess of $\underline{y}^{f,z}$. We link this lower-bound of the wealth support to the distribution of initial endowments by specifying that the lower-bound is 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 $\bar{i}^{f,z}$:

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

B.3 Government

B.3.1 Social Security

Social Security benefits depend on a retiree's past earnings covered under Old Age, Survivors and Divisibility Insurance (OASDI), which are those subject to the payroll tax in our model. We therefore specify that an individual's annual benefits are a function of average lifetime OASDI-covered earnings according to the benefit calculator available from the Social Security Administration.[19] Moreover, since we explicitly model married households, we account for 'spousal benefits'.[20]

To save on state variables, we assume that households do not contemplate the effects on their future social security benefits when making labor supply decisions over their working life. Modeling this expectations channel requires households to consider off-equilibrium paths with respect to social security benefits when labor supply decisions are made. Nonetheless, for the on-equilibrium path, an individual's labor supply choices — and hence their OASDI-covered earnings — are consistent with the actual social security benefits they receive in retirement.

[18]See Appendix A for an explanation of the rental housing choice.

[19]While in practice, OASDI-covered earnings from the highest 35 years are used in the benefit calculation, for simplification purposes we assume benefits depend on the full 40 years of working life for households. See https://www.ssa.gov/pubs/EN-05-10070.pdf for a description of the benefit calculation.

[20]'Spousal Benefits' allow for the low-earning member of a married household to claim one-half of their spouses' benefit when it is greater than their own.

B.3.2 Public Debt and Interest Rate

We internally calibrate the federal debt-output ratio to be 54.2% in the initial steady state, which reflects federal debt held by the public less financial assets and debt held by the Federal Reserve at the end of 2017.[21] We then assume that 61.2% of this debt is held by foreign entities outside of the model,[22] and follow Penn-Wharton Budget Model (2016) by setting $\kappa^{dom} = 0.60$ so that 40% of new federal debt issues are assumed to be purchased by exogenous foreign-entities. Because the initial stock of federal public debt is assumed to be exogenous, and because the state-local government does not issue debt, the flow budget constraints (2.30) and (2.38) hold in the initial steady state by allowing consumption expenditures to take on the residual value.

The real rate of interest on federal government debt as in equation (2.24) is assumed be linear in the real interest rate on private debt and nonlinear in the federal debt-output ratio, the latter of which includes foreign-held debt. We exogenously set the coefficient on the exponentiated debt-output ratio to $\varsigma = 0.1910$ so that the real interest rate on public debt 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). We calibrate the coefficient on the private real interest rate, ϖ, internally to target a ratio of net federal interest payments relative to output equal to 2.1%, which is the average projected value over 2017-2027 in *The Budget and Economic Outlook: 2017 to 2027*.

B.3.3 Public Capital

For purposes of accounting, we allow for the stock of productive public capital to be split between the federal and state-local government. We follow Ramey (2020) and include only non-defense public capital, which we calibrate internally to the 2007-2016 average from NIPA of 63.85% of aggregate output. Of this public capital, we attribute the 2007-2016 average from NIPA of 13.79% to the federal government, with the residual attributed to the state-local government. We follow Congressional Budget Office (2016) and set the time-to-build parameters for federal investment to $S = 20$ and:

$$\begin{aligned}\kappa^{fed}\,|_{s=1}^{S} = \{&0.05, 0.20, 0.15, 0.10, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.02,\\ &0.02, 0.02, 0.02, 0.02, 0.02, 0.02, 0.02, 0.02, 0.02\}\end{aligned}$$

This timing of productivity effects incorporates physical infrastructure, education, and research and development, the latter two of which take longer to become fully productive.

[21] We calibrate to a level of federal debt held by the public less financial assets of relative to output of 69.3%, which is the value projected for 2017 in *The Budget and Economic Outlook: 2017 to 2027* by the CBO. We then net out the 21.7% of debt held by the public was held by Federal Reserve Banks at the beginning of fiscal year 2018.

[22] See the Department of Treasury / Federal Reserve Board report on major foreign holders of treasury securities: https://ticdata.treasury.gov/Publish/mfh.txt.

Congressional Budget Office (2016) and Congressional Budget Office (2021) estimate that increases in federal government investment in public capital are partially offset by decreases in state and local government investment in public capital. For purposes of our state-local government reaction function in equation (2.41), we follow Congressional Budget Office (2021) and assume that $\kappa^{sl} = 0.15$.

B.4 Taxes

B.4.1 Households

Each household is assumed to be one tax unit, so that their net tax liability $\mathcal{T}_{t,j}^{f,z}$ is equal to the sum of their federal income and payroll tax liabilities, $\mathcal{T}_t^{\boldsymbol{i}}(i_{t,j}^{f,z}, r_t^p a_j)$, federal wealth tax liability, $\mathcal{T}_t^{\boldsymbol{w}}(h_j^o, a_j)$, and state-local income, sales, and property tax liabilities, $slt_{t,j}^{f,z}$, less federal transfer payments, trs_t:

$$\mathcal{T}_{t,j}^{f,z} = \mathcal{T}_t^{\boldsymbol{i}}(i_{t,j}^{f,z}, r_t^p a_j) + \mathcal{T}_t^{\boldsymbol{w}}(h_j^o, a_j) - trs_t + slt_{t,j}^{f,z}$$

where the specification of a household's wealth tax liability is described in Section 3.

The object $\mathcal{T}_t^{\boldsymbol{i}}(i_{t,j}^{f,z}, r_t^p a_j)$ is composed of federal income taxes, $fit_{t,j}^{f,z}$, and payroll taxes, $prt_{t,j}^{f,z}$.

$$\mathcal{T}_t^{\boldsymbol{i}}(i_{t,j}^{f,z}, r_t^p a_j) = fit_{t,j}^{f,z} + prt_{t,j}^{f,z}$$

To determine $fit_{t,j}^{f,z}$, we use the Moore and Pecoraro (2021) internal tax calculator framework. This framework is a mapping from a household's adjusted gross income (AGI) to their federal income tax liabilities that explicitly models major statutory individual tax provisions of the Internal Revenue Code.[23] It allows for us to account for the joint taxation of ordinary capital and labor income, the special taxation of preferential capital income, as well as credits and deductions that depend on households' tax-preferred consumption choices and family composition. As Moore and Pecoraro (2020, 2021) show that these income tax details have quantifiable general equilibrium effects, they are included in our wealth tax analysis so that we fully capture economic and budgetary effects that arise due to the underlying income tax system.

The primary input to the internal tax calculator — a household's AGI — is obtained from a household's total economic labor and capital income by scaling each income source by a time- and policy-invariant 'calibration ratio'.[24] For labor income, we specify a

[23] The tax calculator explicitly models the following provisions as specified 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, net investment income surtax, additional medicare tax, personal and dependent exemptions, standard deduction, home mortgage interest deduction, state and local income, sales, and property tax deductions, charitable giving deduction, earned income credit, child tax credit, and the dependent care credit.*

[24] A calibration ratio represents the portion of that income source included in adjusted gross income.

calibration ratio $\chi_j^{\boldsymbol{i};f,z}$ that depends on a household's family composition, productivity type, and age group (working or retired). A household's adjusted gross labor income $\hat{i}_{t,j}^{f,z}$ is then:

$$\hat{i}_{t,j}^{f,z} \equiv \chi_j^{\boldsymbol{i};f,z} i_{t,j}^{f,z}$$

where the tilde accent is used to denote a variable that has been adjusted by a calibration ratio. For capital income, we specify a calibration ratio $\chi_j^{\boldsymbol{a};f}$ that similarly depends on family composition and age group, but is independent of productivity type because of imperfect correlation between household labor and capital income. Instead, we assume that a household's capital income calibration ratio depends on their relative location in the conditional financial wealth distribution $\boldsymbol{f}(a|f,j)$ so that:

$$\chi_j^{\boldsymbol{a};f} = \boldsymbol{\chi}^{\boldsymbol{a}}(\boldsymbol{f}(a|f,j))$$

A household's adjusted gross capital income is then:

$$r_t^p \hat{a}_j^{f,z} \equiv r_t^p \chi_j^{\boldsymbol{a};f} a_j^{f,z}$$

The labor income calibration ratio is exogenously computed as the portion of total economic labor income[25] included in AGI for each (f, z, j) demographic group using the JCT-ITM. The capital income calibration ratio is assumed to be piecewise-linear over financial wealth, and internally calibrated so that within each (f, j) demographic group the average amount of capital income included in AGI for each $\{0-20;\ 21-40;\ 41-60;\ 61-80;\ 81-90;\ 91-99;\ 99-99.9;\ 99.9-100\}$ percentile class of capital income in the model matches those values estimated by the JCT-ITM for calendar year 2017. The close fit of our model's adjusted gross labor income and adjusted gross capital income to the data is shown in Tables A3 and A4.

While ordinary capital income is taxed jointly with labor income as a single base, preferential capital income is taxed separately at lower rates.[26] We decompose adjusted gross capital income to account for this differential taxation as follows: Let $s_{t,k}^{\boldsymbol{o}}$ denote the endogenous share of a household's ordinary capital income of type k at time t, which is uniform across households because the portfolio composition of financial assets are homogeneous within the model.[27] A household's ordinary and preferential capital income

[25] See Section B.1.2 for a definition of economic labor income

[26] Ordinary capital income includes noncorporate business income, interest income, short-term capital gains, and nonqualified dividends. Preferential capital income includes long-term capital gains and qualified dividends. In 2017, approximately 58.6% capital income included in AGI was considered preferential income. In 2017, there were seven tax brackets on the ordinary income statutory tax schedule - with rates of 10, 15, 25, 28, 33, 35, and 39.6 percent - and three brackets on the preferential income schedule - with rates of 0, 15, and 20 percent. In both cases, the applicable rates depend on income ranges that vary with filing status.

[27] The variable $s_{t,k}^{\boldsymbol{o}}$ is endogenous and time-variant because it depends on the portfolio allocation chosen by the financial intermediary in each period.

can be expressed as:

$$r_t^p \hat{a}_{t,j}^{\boldsymbol{o},f,z} \equiv r_t^p \left(\sum_k \chi_k^{\boldsymbol{o}} s_{t,k}^{\boldsymbol{o}} \right) \hat{a}_{t,j}^{f,z}$$
$$r_t^p \hat{a}_{t,j}^{\boldsymbol{p},f,z} \equiv r_t^p \left(\sum_k \chi_k^{\boldsymbol{p}} (1 - s_{t,k}^{\boldsymbol{o}}) \right) \hat{a}_{t,j}^{f,z}$$

where the time- and policy-invariant calibration ratios $\chi_k^{\boldsymbol{o}}$ and $\chi_k^{\boldsymbol{p}}$ are internally calibrated in the initial steady state to match the aggregate tax revenue to output ratio for each ordinary and preferential capital income type k as computed using the JCT-ITM. Table A5 shows the model fit for ordinary and preferential capital income tax liabilities.

The second component of a household's federal tax liabilities is their payroll tax liability $prt_{t,j}^{f,z}$, which are Federal Insurance Contributions Act (FICA) and Self Employment Contributions Act (SECA) contributions for the Old Age, Survivors, and Disability Insurance (OASDI) program, and contributions for the Medicare program. So that we can properly account for the individual-level taxable maximum income level for FICA/SECA contributions, we assume that both the employee- and employer-portion are combined and remitted by households. In 2017, combined FICA/SECA contributions are 12.4% of covered-wages up to a threshold of $\bar{\mathcal{SS}} = \$127,200$ for the OASDI program, and 2.9% of uncapped covered-wages for the Medicare program.[28] Unlike the federal income tax, which treats income from spouses filing a joint return as a single base, the payroll tax base for each spouse is independent. Therefore:

$$prt_{t,j}^{f,z} = \begin{cases} 0.124 \times \chi^{\boldsymbol{\mathcal{SS}}} \chi_j^{\boldsymbol{i};s,z} \times \min\left(n_j w_t \mathrm{z}_j^{s,z}, \bar{\mathcal{SS}}\right) + 0.029 \times \chi^{\boldsymbol{\mathcal{MED}}} \hat{i}_{t,j}^{s,z} & \text{for } f = s,\ j < R \\ 0.124 \times \chi^{\boldsymbol{\mathcal{SS}}} \chi_j^{\boldsymbol{i};m,z} \times \left(\min\left(n_j^1 w_t \mathrm{z}_j^{m,z}, \bar{\mathcal{SS}}\right) + \min\left(\mu^z n_j^2 w_t \mathrm{z}_j^{m,z}, \bar{\mathcal{SS}}\right)\right) & \\ \qquad\qquad +0.029 \times \chi^{\boldsymbol{\mathcal{MED}}} \hat{i}_{t,j}^{m,z} & \text{for } f = m,\ j < R \\ 0 & \text{for } f = s, m,\ j \geq R \end{cases}$$

where $\chi^{\boldsymbol{\mathcal{SS}}}$ and $\chi^{\boldsymbol{\mathcal{MED}}}$ are internally calibrated so that OASDI and Medicare tax receipts relative to output are about 4.38% and 1.34%, as estimated by the CBO for 2017.

A household's federal transfer payments are equal to a uniform lump-sum net transfer, trs, which is set to be equal to 0.40% of aggregate output to represent federal transfers (less those for Old Age and Survivors Insurance, Medicare, Medicaid, and the outlay portion of federal tax credits) less federal excise and miscellaneous taxes.

A household's state-local tax liabilities are assumed to depend linearly each on their

[28] The Additional Medicare Tax of 0.9% on earnings above \$200,000 and \$250,000 for individual- and joint-filers are modeled as part of federal income taxes $fit_{t,j}^{f,z}$.

adjusted gross wage income, owner-occupied housing property, and market consumption:

$$slt_{t,j}^{f,z} \equiv \tau^{sli}\hat{i}_{t,j}^{f,z} + \tau^{slp} h_j^o + \tau^{slx} c_j^M$$

The linear state and local tax income rate τ^{sli}, property tax rate τ^{slp}, and sales tax rate τ^{slx} are each calibrated internally so that total tax revenues from each source are equal to 2.08%, 2.95%, and 2.03% of GDP as estimated by the Census Bureau for 2017.

Finally, a household who dies at the end of any given age $\underline{j}$ may be subject to federal taxes on the value of their taxable estate, $\chi^E y_{\underline{j}+1}$, where χ^E is a calibration ratio set internally so that the ratio of aggregate estate taxes to output is 0.0012 as estimated by the CBO for 2017. Federal estate taxes, $\mathcal{T}_t^{\boldsymbol{est}}(y_{\underline{j}+1})$, are a piecewise linear function of a household's taxable estate, less applicable deductions and exemptions, which are modeled explicitly according to 2017 tax law.

B.4.2 Firm Taxation and the Financial Intermediary

We specify that tax liabilities for both corporate and noncorporate firms, txl_t^q, take the following form:

$$txl_t^q = \tau_t^q \left(Y_t^q - ded_t^q\right) - crd_t^q \quad \text{for } q = c, n$$

where τ_t^q is an aggregate effective marginal tax rate (EMTR) on net business income, ded_t^q are deductions from gross income, and crd_t^q is a credit against gross federal tax liability.

The aggregate EMTR on corporate income is exogenously set to $\tau_t^c = 0.277$, which is the return-weighted[29] rate computed using the JCT Corporate Model[30] for calendar year 2017. The aggregate EMTR on noncorporate income is exogenously set to $\tau_t^{nc} = 0.333$, which is the income-weighted value computed using the JCT-ITM for calendar year 2017.

Deductions from income allowed for firms include wage expense, interest expense, tax depreciation of capital, and state and local tax liabilities (for corporate sector only). We therefore set:

$$ded_t^q = w_t N_t^q - i_t B_t^q - \left(\varrho^q I_t^q + \hat{\delta}^q da_t^q\right) - slt_t^c\left(\boldsymbol{I}_{q=c}\right) \quad \text{for } q = c, n$$

where ϱ^q is the capital investment expense ratio, $\hat{\delta}^q$ is tax depreciation rate of capital, $da_t^q \equiv (1-\hat{\delta}^q)da_{t-1}^q + (1-\varrho^q)I_t^q$ is current depreciation allowances. We exogenously set $\varrho^q = 0$ for simplicity and calibrate $\hat{\delta}^c = \hat{\delta}^n = 0.0056$ internally so that our initial steady state baseline reproduces a ratio of depreciation allowances to aggregate output consistent with that computed using the JCT Depreciation Model[31] for calendar year 2017.

[29]We choose return weights over income weights for this computation so that we can include C-corporations with zero taxable income.
[30]See Joint Committee on Taxation (2011) for a description of the JCT Corporate Model.
[31]See Joint Committee on Taxation (2011) for a description of the JCT Depreciation Model.

We endogenously calibrate the lump-sum credits crd_t^q in a time-invariant fashion 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 using the JCT-ITM. Unlike corporate income, which is taxed at the firm level, noncorporate income is taxed at the household level jointly with other household income. The noncorporate income tax liabilities described here therefore do not affect the firm's cash flow equation (2.18). However, because the noncorporate firm's behavior must be consistent with the implied tax liabilities on its distributions to households, these liabilities affect the firm's value as in equation (2.16). Double-counting is avoided as only the latter enters the federal government's budget constraint.

The aggregate EMTR on dividend and interest income, as well as the accrual-equivalent tax rate on gains, enter the expressions for firm value in each sector. We exogenously set $\tau_t^d = 0.203$, and $\tau_t^i = 0.279$ in a time-invariant fashion, which are the income-weighted values computed by the JCT-ITM for calendar year 2017. We internally calibrate $\tau_t^g = 0.0521$ so that aggregate capital gains tax revenue is 0.67% of aggregate output.

Finally, tax liabilities owed by corporations at the state-local level are assumed to be proportional to aggregate corporate earnings:

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

The linear state and local tax rate on corporate income τ^{slc} is internally calibrated so that state-local corporate income tax receipts are about 0.28% of aggregate output as estimated by the Census Bureau for 2017.

Table A1: Select Exogenous Parameters

Demographics		
Terminal ages	R, J	40, 76
Rate of population growth	υ_P	0.0076
Production		
Rate of technological progress	υ_A	0.0108
Private capital share of output	α	0.353
Public capital share of output	g	0.078
Private capital depreciation rate	δ^K	0.0799
Corporate dividend payout ratio	$\varkappa^d$	0.130
Debt-capital ratio	$\varkappa^{b,c}$, $\varkappa^{b,n}$	0.315, 0.055
Output scale parameter	Z^c, Z^n	1.045, 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	$\underline{\mathrm{h}}^o$	0.925
Preferences		
Subjective discount factor	β	0.940
Non-housing consumption share of composite	σ	0.315
Housing/non-housing consumption substitution parameter	η	-1.053
Utility curvature parameter	$\zeta^{f,\epsilon}$	5
Intensive labor margin disutility	ψ^s,$\psi^{m,1}$,$\psi^{m,2}$	$324.0, 219.0, 110.1$
Extensive labor margin fixed cost	ϕ^s, ϕ^m	$0.323, 0.079$
Government		
Public capital depreciation rate	δ^g	0.0317
Interest rate response to debt	ς	0.0145

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

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

Table A3: Baseline Average Adjusted Gross Labor Income and Federal Labor Income Tax Liabilities (in thousands of 2018$)

	Income				Taxes			
	Target	**Model**	**Target**	**Model**	**Target**	**Model**	**Target**	**Model**
Productivity	Single		Married		Single		Married	
1	3.0	3.0	16.8	16.8	-0.4	-0.4	-2.8	-2.8
2	15.0	15.1	52.0	51.9	-2.5	-2.5	0.1	0.1
3	28.5	28.6	83.3	83.4	-0.2	-0.2	5.4	5.4
4	44.6	44.4	123.3	123.8	3.0	3.0	12.2	12.4
5	64.8	64.9	176.1	176.9	6.8	6.9	23.8	23.9
6	105.8	105.8	318.7	319.9	15.6	15.5	64.5	64.7
7	276.8	278.1	1,459.6	1,466.7	61.0	60.9	409.7	410.8
8	1,450.7	1,451.8	5,522.6	5.522.3	419.2	419.5	1,776.1	1,774.3

Table A4: Baseline Average Adjusted Gross Capital Income (in thousands of 2018$)

	Working-Age				Retired			
	Target	**Model**	**Target**	**Model**	**Target**	**Model**	**Target**	**Model**
Percentile	Single		Married		Single		Married	
0 – 20	0.0	0.0	0.0	0.0	0.3	0.0	1.6	0.0
20 – 40	0.0	0.0	0.0	0.0	1.6	1.6	7.7	7.1
40 – 60	0.0	0.0	0.0	0.0	7.0	7.0	24.0	23.9
60 – 80	0.0	0.0	1.4	1.4	21.5	21.4	48.9	48.6
80 – 90	0.8	0.8	7.9	7.8	43.2	43.0	83.9	83.5
90 – 99	9.9	9.9	73.0	72.5	93.0	92.5	165.5	164.6
99 – 99.9	129.8	129.0	770.4	766.3	330.6	329.1	628.8	625.4
99.9 – 100	2,469.2	2,470.8	1,013.3	1,013.2	2,594.2	2,603.5	4,938.2	4,947.8

Table A5: Baseline Aggregate Household Capital Income Tax Ratios

Target Ratio	**Target**	**Model**
Ordinary Capital Income Tax Revenue to Aggregate Output Ratio	0.0153	0.0153
Preferential Capital Income Tax Revenue to Aggregate Output Ratio	0.0079	0.0080

C Trend-Stationary Equilibrium

We formally define an equilibrium in terms of a trend-stationary transformation of the model. Variables with the tilde accent denote those that have been de-trended for technological and/or population growth. Following Moore and Pecoraro (2020, 2021), we perform a change of variables to mitigate the curse-of-dimensionality problem by reducing the two-dimensional household state space to a single dimension of net worth $\tilde{y} \equiv \tilde{a} + \tilde{h}^o$.

For each age cohort, j, productivity type, z, and family composition f, households have market consumption, $\tilde{c}^M$, charitable giving, $\tilde{c}^g$, market labor hours, n, n^1, and n^2, owner-occupied housing assets, $\tilde{h}^o$, rental housing $\tilde{h}^r$, 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.

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 $\{\tilde{c}^{M;f,z}_{t,j}(\tilde{y})$, $\tilde{c}^{g;f,z}_{t,j}(\tilde{y})$, $n^{z,s}_{t,j}(\tilde{y})$, $n^{z,m,1}_{t,j}(\tilde{y})$, $n^{z,m,2}_{t,j}(\tilde{y})$, $\tilde{h}^{o;f,z}_{t,j}(\tilde{y})$, $\tilde{h}^{r;f,z}_{t,j}(\tilde{y})$, $\tilde{a}^{f,z}_{t,j}(\tilde{y})$; $\tilde{y}^{f,z}_{t+1,j+1}(\tilde{y})\}$, 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:*

$$\begin{aligned}
\tilde{N}_t &= \int_{\mathbb{Z}}\int_{\mathbb{J}} \tilde{\Omega}^{z,s}_{t,j} z^{z,s}_j n^{z,s}_{t,j}(\tilde{y}) + \tilde{\Omega}^{z,m}_{t,j} z^{z,m}_j \left(n^{z,1}_{t,j}(\tilde{y}) + n^{z,2}_{t,j}(\tilde{y})\right)\ dj\ dz \\
\tilde{H}^o_t &= \int_{\mathbb{Z}}\int_{\mathbb{J}} \sum_{f=s,m} \tilde{\Omega}^{f,z}_{t,j} \tilde{h}^{o;f,z}_{t,j}(\tilde{y})\ dj\ dz \\
\tilde{H}^r_t &= \int_{\mathbb{Z}}\int_{\mathbb{J}} \sum_{f=s,m} \tilde{\Omega}^{f,z}_{t,j} \tilde{h}^{r;f,z}_{t,j}(\tilde{y})\ dj\ dz \\
\tilde{D}_t &= \int_{\mathbb{Z}}\int_{\mathbb{J}} \sum_{f=s,m} \tilde{\Omega}^{f,z}_{t,j} \tilde{a}^{f,z}_{t,j}(\tilde{y})\ dj\ dz \\
\tilde{\mathcal{C}}_t &= \int_{\mathbb{Z}}\int_{\mathbb{J}} \sum_{f=s,m} \tilde{\Omega}^{f,z}_{t,j} \left((\tilde{c}^{M;f,z}_{t,j}(\tilde{y}) + \tilde{c}^{g;f,z}_{t,j}(\tilde{y}) + \tilde{\kappa}^{f,z}_{t,j}\right)\ dj\ dz + \tilde{c}^E_t
\end{aligned}$$

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

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

$$\begin{aligned}
\tilde{N}_t &= \sum_{q=c,n} \tilde{N}^q_t(\tilde{K}_t{}^q) \\
\tilde{K}_{t+1} &= \sum_{q=c,n} \tilde{K}^q_{t+1}(\tilde{K}_t{}^q) \\
\tilde{B}_t &= \sum_{q=c,n} \varkappa^{b,q} \tilde{K}_t{}^q
\end{aligned}$$

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:

$$R^c_t - \tau^{cw}_t = R^n_t - \tau^{ncw}_t = (1-\tau^i_t)i_t - \tau^{bw}_t = (1-\tau^r_t)(p^r_t - \delta^r) - \tau^{rw}_t$$

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

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

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:*

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

where private aggregate investment is defined as:

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

with:

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

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:

$$\begin{aligned}
\tilde{I}_t^{fed} &= (1/\kappa_1^{fed}) \left(\tilde{G}_{t+1}^{fed} (\Upsilon_P \Upsilon_A) - (1-\delta^g)\tilde{G}_t^{fed} - \sum_{s=2}^{S} \kappa_s^{fed} \tilde{I}_{t-s+1}^{fed} (\Upsilon_P \Upsilon_A)^{-s+1} \right) \\
\tilde{I}_t^{sl} &= \tilde{G}_{t+1}^{sl} (\Upsilon_P \Upsilon_A) - (1-\delta^g)\tilde{G}_t^{sl}
\end{aligned}$$

and where the implied trade balance is:

$$\tilde{\mathcal{TB}}_t \equiv (1-\kappa^{dom}) \left(\tilde{B}_t^{g,tot}(1+\rho_t) - \tilde{B}_{t+1}^{g,tot} (\Upsilon_P \Upsilon_A) \right)$$

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

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

and maintains a fiscally sustainable path so that:

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

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

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

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

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

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:

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

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

and:

$$\tilde{I}_t^{sl} = \tilde{I}^{sl} - \kappa^{sl} \left(\tilde{I}_t^{fed} - \tilde{I}^{fed} \right)$$

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

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

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:*

$$\tilde{c}^E_t + t\tilde{x}l^{est}_t + \tilde{Beq}_t = (\Upsilon_A)\int_{\mathbb{Z}}\int_{\mathbb{J}}(1-\pi_j)\sum_{f=s,m}\tilde{\Omega}^{f,z}_{t,j}\tilde{y}_{t+1,j+1}\ dj\ dz$$

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.*

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