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Winners and Losers from Property Taxation

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This paper considers optimal taxation of housing capital. To this end, we employ a life-cycle model calibrated to the U.S. economy, where asset holdings and labor productivity vary across households, and tax reforms lead to changes in house and rental prices, interest rates, and wages. We find that the optimal property tax in the long run is considerably higher than today, partly due to the relatively inelastic demand and supply of housing. A higher property tax also reduces house prices and causes a reallocation from housing to business capital, which in turn decreases interest rates and increases wages. These equilibrium effects allow for an improved consumption smoothing over the life cycle. However, most current households would incur substantial welfare losses from an implementation of a higher property tax, since house prices fall, and a majority own their home. Hence, when accounting for transitional dynamics, it is not clear that a higher property tax is feasible or preferred.

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1. Introduction

The remarkable increase in housing wealth has been a striking global trend over the last seventy years. In many countries, housing now constitutes a substantially larger share of

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domestic capital than before (Alvaredo et al. (2018)). The prominent role of housing has had wide-ranging implications for our view on, e.g., fiscal policy (Kaplan and Violante (2014)), monetary policy (Kaplan et al. (2018)), economic crises (Mian and Sufi (2011)), and inequality (Piketty (2014)). Hence, it is notable that we have yet to appreciate that an increasing share of the tax base comprises housing wealth and that this is likely to impact how governments should finance their expenditures. Actual tax policies appear largely unaffected: property taxes as a share of GDP and total taxes have on average remained stable for the OECD countries since the mid-1960's (OECD, 2021).

The fundamental change in the composition of aggregate wealth raises a key question of how we should tax the various types of capital, and in particular, housing capital. We address this question by first analyzing the optimal property tax in the long run.[1] We then consider how current households would be affected by a tax reform, by accounting for the transitional dynamics. The tax experiments are studied by using a quantitative general-equilibrium heterogeneous-agent model.

Two main findings stand out. First, we find that the optimal property tax in the long run is significantly higher than today.[2] A higher property tax reduces house prices and causes a reallocation from housing capital to business capital, which leads to a reduction in interest rates and an increase in the wage rate. Importantly, these equilibrium effects allow for an improved consumption smoothing over the life cycle, as young households become less constrained. These mechanisms have so far been overlooked in the literature on optimal property taxation. A higher property tax is also beneficial since the demand and supply of housing capital are relatively inelastic, as compared to business capital. Second, we show how and why welfare effects differ across households, when accounting for the implementation phase of a tax reform. Newborn generations largely benefit from a higher property tax rate, but the benefit is lower for high-income households and households born closer to the time of the reform. In contrast, homeowners and retirees that are alive when the reform is implemented incur significant welfare costs. Consequently, most of current households are negatively affected from an increase in the property tax, which highlights that implementing the long-run optimal tax policy may be neither feasible nor desirable.

To study the welfare effects of tax reforms, we use a general-equilibrium life-cycle model with overlapping generations and incomplete markets. The model allows for welfare effects that differ across important household characteristics, such as age, income, and homeownership. In addition, the overlapping nature of the model makes it possible to study how the welfare effects vary over time. The general-equilibrium aspect is valuable, as changes to tax rates are likely to have aggregate effects on the demand for housing and other types of assets, as well as labor supply. Thus, we allow house and

[1] We consider revenue-neutral policies, and thus, follow a long tradition in public finance that considers a consolidated government budget even if some taxes are set at different government levels. In the baseline analysis, a change in the property tax is made revenue-neutral by altering the capital-income tax. However, we show that the results and the mechanisms are largely the same if we instead adjust the tax on labor income or consumption.

[2] We consider both aggregate efficiency and utilitarian welfare. These yield similar results. We therefore focus on utilitarian welfare and report the main results for aggregate efficiency in the appendix.

rental prices, interest rates, and wages to respond endogenously to changes in taxes. In the quantitative exercises, we use the U.S. as a laboratory, where the foundation of the analysis is that we take the current tax system as given. Moreover, we consider a consolidated view of the tax system, as it is a valuable starting point. The model matches the data along key variables for the analysis, including the homeownership rate and net worth relative to earnings over the life cycle. The distribution of house values relative to earnings also captures well the heterogeneity in the U.S. population.

The quantitative analysis consists of two parts. In the first part, we analyze the optimal tax policy in the long run. Hence, we consider the welfare of newborn households in steady state. This is a useful exercise for understanding the costs and benefits for households who are not directly impacted by the implementation phase of a policy. We find that the policy that maximizes aggregate welfare implies a substantially higher property tax rate than today. The higher property tax is coupled with a significant reduction of the capital-income tax, to make the policy revenue neutral. Importantly, the main results and mechanisms are largely the same if we instead reduce labor-income taxes or consumption taxes to balance the government's budget. The optimal policy involves an increase in the property tax from the current level of 1 percent to 7 percent, paired with a reduction of the capital-income tax to approximately -1 percent.

Three main factors explain why a higher property tax is beneficial in the long run. First, as housing is not only a means of saving but also provides utility to households, the demand for housing is relatively inelastic. As a result, a higher property tax has limited distortionary effects on households' behavior. Second, the supply of housing is also relatively inelastic. Finally, a higher tax on housing reduces house prices and causes a reallocation of the capital stock towards business capital, which lowers interest rates and increases wages. These general-equilibrium effects have important implications for welfare. Higher wages benefit households of all ages, whereas lower house prices and interest rates benefit primarily the young, who are able to better smooth consumption over the life cycle.

This paper also sheds new light on how optimal property taxes in the long run varies across households. Specifically, we see that the preferred steady-state property tax is decreasing in households' labor income. Households with low labor productivity benefit relatively more from higher property taxes, due to both the higher wages and lower interest rates, as well as lower equilibrium house prices. Households with high initial labor productivity, on the other hand, reap benefits from the low property tax in the current tax code as many of them can reduce their overall tax payments by investing in owner-occupied housing.

The gains and losses from higher property taxes may be very different once the transitional dynamics are included. First, the welfare effects are likely to differ across generations. Higher wages, due to an increase in business capital, is a key benefit of shifting the tax burden toward properties. But the reallocation of capital is a slow-moving process. Therefore, current generations do not fully capture the long-run benefits. Second, there are likely substantial welfare differences even within generations, especially among households who are alive at the time of a policy change.

In the second part of the quantitative analysis, we therefore consider how the transitional dynamics after a permanent increase in the property tax rate affect households' welfare.[3] We find that a vast majority of households alive at the time of the reform experience significant welfare losses from higher property taxes. Homeowners in particular are negatively affected, as they are hurt by an immediate drop in house prices, which reduces their wealth. Retirees are also worse off as many of them are homeowners, and they benefit little from higher wages and lower interest rates in the future. In fact, the current generations would be better off if the property tax was reduced.

Newborn generations along the entire transition are better off with higher property taxes. They experience costs and benefits that are much alike those in the steady-state analysis. However, since the reallocation of capital takes time, the benefits of higher wages and lower interest rates occur gradually. As a result, the welfare gains of newborn generations are relatively small close to the reform but increase steadily over time.

When the transitional dynamics are accounted for, the optimal property tax depends on what weight is assigned to current relative to future generations. As current generations are hurt by a higher property tax it is politically infeasible to directly implement the tax policy that is optimal in the long run.[4] Moreover, we find that a planner would need to have a social discount factor that is substantially higher than households' discount factor for the optimal property tax to be higher than today's level of 1 percent.

We proceed by exploring whether time-varying policies can make a majority of current households in favor of a policy that entails a higher property tax in the long run. We find that this is possible if the property tax is low for an extended period, although many future generations experience welfare losses from such a policy. Specifically, we consider a simple policy which first lowers the property tax rate to zero before it is increased. Newborns in the long run benefit from such a policy as the long-run property tax is increased. Moreover, a majority of current generations benefit as long as the increase in the property tax occurs far enough in the future. Hence, we show that such a policy may be politically feasible, however, many future generations along the transition to the new steady state are hurt by the reform.

1.1 *Related literature*

This paper contributes to the broad literature on optimal taxation. Key papers include, but are not limited to, Summers (1981), Auerbach et al. (1983), Judd (1985), Chamley (1986), İmrohoroğlu (1998), Atkeson et al. (1999), Domeij and Heathcote (2004), Conesa and Garriga (2008), Straub and Werning (2020), and Dyrda and Pedroni (2023). Of particular relevance for us are the contributions by Aiyagari (1995) and Conesa et al. (2009), who show that positive taxes on capital are warranted if markets are incomplete or when

[3]All policies are assumed to be credible and implemented unexpectedly. Similar once-and-for-all policies are assumed in, e.g., Domeij and Heathcote (2004), Bakış et al. (2015), and Krueger and Ludwig (2016) who study optimal capital taxation, optimal progressivity of the income distribution, and the optimal provision of social insurance, respectively.

[4]A similar status-quo problem is highlighted in the context of a Social Security reform in Conesa and Krueger (1999).

accounting for the life cycle of households. However, our findings are not directly comparable to these results as our main analysis is concerned with the optimal property tax, where we adjust the tax on capital income to keep the tax burden on total capital largely unchanged.

Within the literature on optimal taxation, a relatively new strand of research has emerged that studies optimal capital taxation in a setting with housing capital. Eerola and Määttänen (2013) find that it is optimal to close the gap in taxation between housing and non-housing capital, and to set both taxes to zero as in Chamley (1986) and Judd (1985). Bonnet et al. (2021) distinguish between land and housing structures, and argue for a significant tax on land as it is a fixed factor. However, their setting abstracts from incomplete markets, financial frictions, and household heterogeneity. These aspects are included in Nakajima (2020) and Rotberg (2022), the two papers that we arguably most closely relate to.

Nakajima (2020) studies the optimal capital-income tax under two different assumptions for how imputed rents are taxed, while the labor-income tax is adjusted to balance the government's budget. Our work differs along several dimensions. First, we do not consider a tax on imputed rent, but instead a tax on housing wealth. Second, our focus is on the optimal tax on housing rather than analyzing how business capital should be taxed. We show that the optimal property tax in the long run is significantly higher than the current level of 1 percent, and that this result holds irrespective of whether the government's budget is balanced by lowering the tax on capital income, labor income, or consumption. Third, we show that endogenizing the house-price response to changes in the property tax has important implications for welfare. Lastly, we allow for transitional dynamics, and show that the optimal property tax is substantially lower when accounting for the transitional effects.

The paper by Rotberg (2022) shares our ambition of studying the optimal tax on housing wealth. However, he considers a trade-off between a tax on housing and a flat tax on wealth tied to the stock of productive capital. Rotberg (2022) finds that a low tax on housing and a high tax on wealth is beneficial. This result relies on two important assumptions. First, he assumes that housing consumption is relatively more important for low-income households. Second, he assumes that the productivity of capital depends on who owns it. As a result, the flat wealth tax is equivalent to a regressive capital-income tax, which generates a more efficient allocation of business capital. Our findings, on the other hand, highlight that a higher property tax benefits low-income households in particular, due to the equilibrium effects of lower house prices and mortgage interest rates. We also show that this result holds regardless if a tax on capital income, labor income, or consumption is used to clear the government budget. Furthermore, we emphasize a status-quo problem of implementing a higher property tax, by analyzing the transitional dynamics.

Our paper also relates to the growing macro-housing literature. This line of work uses quantitative dynamic general equilibrium models to study a broad set of questions, such as the causes of the housing boom and bust around the Great Recession (Kaplan et al., 2020) and consumption responses to house-price shocks (Berger et al., 2018). Other papers are concerned with the welfare effects of reducing the preferential tax treatment of housing, but do not consider optimal policies. Influential contributions include Skinner (1996), Gervais (2002), Chambers et al. (2009), and Sommer and Sullivan (2018). More concretely, these papers study the welfare effects of either setting the tax on imputed rent of owner-occupied housing equal to the capital-income tax, or removing the mortgage interest deductibility. In addition to solving for optimal taxes, our paper differs from these studies by considering the welfare effects of changing the property tax. We highlight that the general equilibrium effects on house prices and interest rates of a higher property tax are beneficial for consumption smoothing over the life cycle. Hence, a key mechanism behind our results comes from the interaction between changes in aggregates and the presence of borrowing constraints. As such, our paper also relates to the work by Dávila et al. (2012) and Park (2018).

The rest of the paper is organized as follows. In Section 2, we present a general equilibrium life-cycle model with heterogeneous households that captures salient features of the U.S. housing market and tax system. The calibration of the model is then discussed in Section 3. In Section 4, we study optimal property taxation in the long run, whereas Section 5 considers welfare effects of tax policies when including the dynamics following a reform. Section 6 concludes. Supplemental Appendix (Balke et al., 2025) presents equilibrium definitions, market-clearing conditions, and additional analysis relating to the Chamley (1986) paper and alternative welfare measures, as well as robustness exercises in terms of housing-supply elasticity, intertemporal elasticity of substitution, and bequests.

2. Quantitative model

There are five types of agents in the quantitative model, namely, heterogeneous households, a representative production firm, a financial intermediary, a construction firm, and a government. Households enter the economy with unequal amounts of initial assets, face uncertain labor productivity during their working age, and are subject to an age-dependent probability of dying. Households' utility is increasing in non-housing and housing consumption and decreasing in labor supply. They receive warm-glow utility from leaving bequests. Housing services can either be obtained by renting from a financial intermediary or by owning a house. House purchases are long-term investments due to lumpy transaction costs of buying and selling houses. Households can thus save by investing in deposits or by building up housing equity. Borrowing is limited to homeowners, and they have to adhere to a loan-to-value constraint. In line with the U.S. tax code, there is a progressive labor-income tax schedule. There are also proportional taxes levied on capital income, consumption, and housing.

A representative firm produces goods using labor and capital as inputs. A financial intermediary lends capital to the firm, provides homeowners with mortgages, and rents out housing services to tenants. Its operations are financed by households' deposit savings. The government operates a pay-as-you-go social security system, collects and distributes bequests, and taxes households, the financial intermediary, and the construction firm. Housing investments by the construction firm depend positively on the house price and a fixed amount of new land.

In the benchmark model, the interest rate adjusts to clear the capital market, the wage rate ensures that the labor market clears, the house price adjusts to equalize aggregate housing supply and demand, and the price of rental housing is endogenous. The model is in discrete time, where one model period corresponds to three years. For ease of notation, we only write variables with subscripts for individuals i, age j, and time t where it is needed to avoid confusion.

2.1 *Households*

Demographics The economy is populated by a measure one of households. Households can live at most 20 model periods, i.e., 60 years. They enter the economy at age $j=1$, work until $j=J_r$ and cannot live past $j=J$. The probability of surviving between any two ages j and $j+1$ is $\phi_j \in [0,1]$.

Endowments and labor earnings Households choose how much time to dedicate to work on a period-by-period basis. Each unit of time worked $l_{i,j,t}$ translates into $n_{i,j} l_{i,j,t}$ units of labor supply, where $n_{i,j}$ denotes the worker's labor productivity. During working age, labor productivity is uncertain. Specifically, the productivity of household i at age j is given by

$$n_{i,j} = \begin{cases} g_j \pi_{i,j} & \forall j \le J_r \\ 0 & \forall j > J_r \end{cases}$$

where g_j is a deterministic age-dependent component common across households, and $\pi_{i,j}$ is a persistent productivity component. Specifically, the logarithm of the persistent component follows an AR(1) process

$$\log(\pi_{i,j}) = \begin{cases} \rho \log(\pi_{i,j-1}) + \nu_{i,j} & \forall j \in \{2, ..., J_r\} \\ \nu_{i,j} + \xi_i & \text{for } j = 1, \end{cases}$$

where $\rho \in [0,1]$ captures the persistence of productivity, $\nu_{i,j}$ is an i.i.d. shock distributed $N(0,\sigma_\nu^2)$, and ξ_i is an initial shock component with distribution $N(0,\sigma_\xi^2)$.

Pre-tax earnings are given by $y_{i,j,t} = w_t n_{i,j} l_{i,j,t}$ during working age, where w_t is the wage level per labor-efficiency unit at time t. Retirement benefits are capped at $w_t \bar{ss}$. Retirement benefits below the cap are given by $\tau^{rr} w_t n_{iJ_r}$, where $\tau^{rr} \in [0,1]$ is the replacement rate and n_{iJ_r} is the productivity in the last working-age period. Formally, $y_{i,j,t} = w_t \min(\tau^{rr} n_{iJ_r}, \bar{ss})$ during retirement. A more detailed description of the productivity components and earnings is provided in Section 3.1.

Households are born with initial assets a_{i1t} as in Kaplan and Violante (2014). During working age, households receive $a_{i,j,t} = \gamma_t w_t n_{i,j-1}$ in the form of bequests, where $n_{i,j-1}$ is the labor productivity in the previous period. As labor is unproductive during retirement, retirees receive bequests as a fraction of their benefits, i.e., $a_{i,j,t} = \gamma_t y_{i,j,t}$ for $j > J_r$. In equilibrium, the parameter γ_t adjusts so that aggregate bequests received by households who are alive equal the amount left by households that die.

Preferences Households derive instantaneous utility from a consumption good c and housing services s. They also receive disutility from working. Formally,

$$U_j(c,s,l) = e_j \frac{\left(c^{\alpha} s^{1-\alpha}\right)^{1-\sigma}}{1-\sigma} - \mu \frac{l^{1+\frac{1}{\varphi}}}{1+\dfrac{1}{\varphi}}$$

for $\sigma \neq 1$, where σ is the parameter of relative risk aversion, e_j is an age-dependent equivalence scale that captures changes in household size over the life cycle (see, e.g., Kaplan et al. (2020)), α is the expenditure share on consumption, μ determines the disutility of working, and φ is the Frisch-elasticity of labor supply.

There is also a warm-glow bequest motive similar to that of De Nardi (2004)

$$U^B(q') = \upsilon \frac{\left(q' + w_t \bar{q}\right)^{1-\sigma}}{1-\sigma},$$

for $\sigma \neq 1$, where υ is the weight assigned to the utility from leaving bequests, q' is households' net worth, and $\bar{q}$ captures the extent to which wealthier households care more about leaving bequests.[5] For example, higher values of $\bar{q}$ mean that poorer households have less incentive to increase their net worth for the purpose of leaving bequests. As preferences are non-homothetic, there is a potential scaling issue: Whenever the wage level increases, income-poor households save disproportionally more due to the decreasing importance of $\bar{q}$. To remedy the scaling problem, we multiply $\bar{q}$ with the wage level w_t. This way, preferences feature scale invariance in the aggregate, while we still allow for non-homothetic preferences in the cross section (see also the discussion in Mian et al. (2020)). The private discount factor is β and the objective of households is to maximize the expected sum of discounted lifetime utility.

Deposits Households can invest any non-negative amount in deposits d'. The interest rate on deposits invested at time t is r_{t+1}.

Houses Housing services can either be obtained by owning a house or renting from the financial intermediary. Each unit of housing costs p_t^h to buy and p_t^r to rent. An owned house of size h' produces housing services through a linear technology $s = h'$. Buying and selling owner-occupied houses are subject to proportional transaction costs. The transaction cost of buying is $\varsigma^b p_t^h h'$. Similarly, the cost of selling a house is $\varsigma^s p_t^h h$, where h is the size of the owner-occupied house a household enters the period with. Housing depreciates at the rate δ^h in each period, and a maintenance of $\delta^h p_t^h h$ must be paid by homeowners.

Housing is available in discrete sizes. The choice set of rental services is restricted to the ordered set of discrete sizes $S = \{\underline{s}, s_2, s_3, ..., \bar{s}\}$. Owner-occupied housing is limited to a set H_{own}, where the smallest house size $\underline{h}$ in H_{own} is larger than the smallest available size in S.[6] Above and including that lower bound, both sets are identical. Formally,

[5]Primes indicate the current period choice of variables that affect next period's state variables.

[6]A minimum size of owner-occupied housing $\underline{h}$ is also assumed in, e.g., Cho and Francis (2011), Floetotto et al. (2016), Gervais (2002), and Sommer and Sullivan (2018).

the discrete housing grids capture both quantity and quality of the house, but henceforth we refer to h and s as the quantity or size of housing.

Mortgages Households can use mortgages m' to finance their homeownership. The interest rate on a mortgage taken up at time t is $r^m_{t+1} = r_{t+1} + \kappa$, where $\kappa > 0$. Mortgages are long-term and non-defaultable. Negative mortgage levels are not allowed, and a household cannot choose a positive level of mortgages in the last period J. The only other restriction is a loan-to-value (LTV) requirement which states that a household can only use a mortgage to finance up to an exogenous share $1-\theta$ of the house value

$$m' \leq (1-\theta)p^h_t h'. \tag{1}$$

The LTV requirement is potentially binding for a household that takes up a mortgage when purchasing a new house or for a household that increases its current mortgage. A household that stays in its home and does not increase its mortgage is not subject to the LTV constraint.

Taxes There are a number of taxes that households pay. Labor income is subject to both a progressive tax $T(y_{i,j,t})$ and a linear payroll tax τ^{ss}_t, the latter is only paid by working-age households as represented by the dummy variable $\mathbb{I}^w$. Both of these taxes are fixed throughout the analysis. The progressive labor-income tax schedule is given by the following function

$$T(y_{i,j,t}) = y_{i,j,t} - \lambda y_{i,j,t}^{\tau^p},$$

where λ determines the tax level and τ^p the amount of progressivity. In addition, there is a linear labor-income tax τ^l_t that is set to zero in the baseline analysis, but that we alter in some of the policy experiments to clear the government budget. For ease of notation, let $\bar{y}_t \equiv (1-\tau^l_t - \mathbb{I}^w\tau^{ss}_t)y_{i,j,t} - T(y_{i,j,t})$ denote after-tax labor income.[7]

The return on deposits is subject to a linear capital-income tax τ^k_t, which gives an after-tax return of $\bar{r}_t \equiv (1-\tau^k_t)r_t$. Consumption is also subject to a linear tax τ^c_t. Lastly, the value of an owner-occupied house is subject to a property tax τ^h_t that is proportional to the house value. In the main policy experiments in this paper, we consider revenue-neutral changes to the property tax rate, which are associated with changes in the capital-income tax. For robustness we also consider clearing the government's budget by changing the tax on labor income or consumption, in response to changes in the property tax.

Recursive formulation of the household problem Households have one deterministic individual state: j for age. They also have non-deterministic individual states, which we denote $\mathbf{z} \equiv (n, x, h, m)$. Recall that n is labor productivity, h is the size of owner-occupied

[7]We do not consider specific tax deductions, such as mortgage interest payments, since a majority of households do not itemize deductions after the Tax Cuts and Jobs Act in 2017. Less than 10 percent of all returns included itemized deductions in the 2021 tax year (Internal Revenue Service, 2024).

housing, and m is the mortgage. The last state variable x represents cash-on-hand and is defined as $x = \bar{y}_t + a$ for $j = 1$ and

$$x = \bar{y}_t + (1 + \bar{r}_t)d - (1 + r_t^m)m + ((1 - \varsigma^s) - \delta^h - \tau_t^h)p_t^h h + a$$

for $j > 1$. For computational reasons, and without any loss of generality, we define cash-on-hand as including the net revenue of selling the house $(1 - \varsigma^s)p_t^h h$. Households who do not sell their house between any two periods do not incur any transaction costs. Initial assets and inheritance are captured by the term a.

The household problem includes the discrete choice of whether to rent a home (R), buy a house (B), or stay in an existing house (S). Then, for each household of age j and living situation $k \in \{R, B, S\}$, the recursive problem can be formulated as follows:

$$V_{j,t}^k(\mathbf{z}) = \max_{c,s,l,h',m',d'} U_j(c, s, l) + \beta \left(\phi_j \mathbb{E}_{j,t}\left[V_{j+1,t+1}(\mathbf{z}')\right] + (1 - \phi_j)U^B(q') \right) \tag{2}$$

subject to

$$\begin{aligned}
&(1 + \tau_t^c)c + d' + \mathbb{I}^R p_t^r s + \mathbb{I}^B(1 + \varsigma^b)p_t^h h' + \mathbb{I}^S(1 - \varsigma^s)p_t^h h \le x + m' \\
&q' = \left(d' + p_t^h h' - m'\right) / \left(\alpha + (1 - \alpha)p_t^h\right) \\
&s = h' \quad \text{if } h' > 0 \\
&h' = 0 \quad \text{if } k = R \\
&m' \ge 0 \quad \text{if } h' > 0 \\
&m' = 0 \quad \text{if } h' = 0 \text{ and/or } j = J
\end{aligned}$$

and $c > 0, s \in S, h' \in H_{own}, d' \ge 0$. The first constraint in the recursive problem is the budget constraint, where the left-hand side of the inequality is total expenditures and the right-hand side is the total resources available to spend. For all $k \in \{R, B, S\}$, a household chooses how much to consume c and how much to save in deposits d'. Additional costs occur depending on the specific living situation. In the renter case $\mathbb{I}^R = 1$, the household needs to pay the cost of renting $p_t^r s$. In the buyer case $\mathbb{I}^B = 1$, the household needs to pay for the house purchase, which also includes a transaction cost. The total cost is thus $(1 + \varsigma^b)p_t^h h'$. As cash-on-hand x is defined such that it includes the value of the house when sold, $(1 - \varsigma^s)p_t^h h$ is added to the budget constraint as an expenditure in the stayer case, i.e., whenever $\mathbb{I}^S = 1$. Households can cover their costs by spending their cash-on-hand x or by borrowing $m' > 0$ whenever they buy or stay in an owner-occupied house. Stayers that increase their mortgage and buyers of new homes have to comply with the LTV constraint (1).

The second constraint in the recursive problem shows that the net worth q', which goes into the warm-glow utility function, is deflated by a price index $\alpha + (1 - \alpha)p_t^h$. This captures the fact that any change in the house price affects the purchasing power of the agent that receives the bequests. The solution to the household problem is given by

$$V_{j,t}(\mathbf{z}) = \max\left\{V_{j,t}^R(\mathbf{z}), V_{j,t}^B(\mathbf{z}), V_{j,t}^S(\mathbf{z})\right\},$$

with the corresponding set of policy functions

$$\left\{c_{j,t}(\mathbf{z}), s_{j,t}(\mathbf{z}), l_{j,t}(\mathbf{z}), h'_{j,t}(\mathbf{z}), m'_{j,t}(\mathbf{z}), d'_{j,t}(\mathbf{z})\right\}.$$

2.2 *Production*

A representative firm uses capital K_t and labor N_t as inputs into a standard neoclassical production function to produce output goods Y_t. Formally,

$$F(K_t, N_t) = Y_t = AK_t^{\alpha_k} N_t^{1-\alpha_k},$$

where A is aggregate productivity and α_k is the capital-income share. As usual the interest rate r_t and wages w_t are given by

$$r_t = A\alpha_k \left(\frac{N_t}{K_t}\right)^{1-\alpha_k} - \delta^k \tag{3}$$

$$w_t = A(1-\alpha_k)\left(\frac{K_t}{N_t}\right)^{\alpha_k}, \tag{4}$$

where δ^k is the depreciation of capital.

2.3 *Financial intermediary*

There is a financial intermediary that operates as a bank and the sole provider of rental services.

Deposits ($D_{f,t}$) All deposits are invested in the intermediary at the interest rate r_{t+1} and finance the intermediary's operations. The subscript f indicates that the variable is specific to the financial intermediary. The intermediary provides mortgages to households, buys and rents out housing to households, and lends capital to the production firm. For simplicity, we assume that the intermediary only lives for two periods and earns zero profits.

Mortgages ($M_{f,t}$) Mortgage lending provides the intermediary with a net return of r_{t+1}. Although households pay an interest rate of $r^m_{t+1} = r_{t+1} + \kappa$, we assume that the mortgage spread κ is a wasteful intermediation cost.

Capital ($K_{f,t}$) The net return on capital lending to the production firm is r_{t+1}.

Rental Stock ($H_{f,t}$) The gross return of rental operations is given by the rental income p^r_t and accrues already in the first period. The operational costs comprise a depreciation cost δ^h, an intermediation cost η, and a property tax τ^h_{t+1} that are all proportional to the value of the rental stock in the second period. The intermediary also incurs a financing cost r_{t+1} as it uses deposits to finance the purchase of the rental stock. After a tax reform is implemented, house prices may change. Let the capital losses per unit of the rental stock be $\Delta p^h_t = (p^h_t - p^h_{t+1})/p^h_t$, i.e., if house prices fall capital losses increase. Expected capital losses and gains are reflected in the rental price, and lead to higher and lower rental rates, respectively. The rental price that ensures zero profits is

$$p_t^r = \frac{1}{1+r_{t+1}} \left((\delta^h + \eta + \tau_{t+1}^h) p_{t+1}^h + (r_{t+1} + \Delta p_t^h) p_t^h \right). \tag{5}$$

A similar, but simplified, zero-profit condition is used in, e.g., Gervais (2002).

2.4 *Housing supply and the construction firm*

At time t a construction firm decides how much new housing capital to produce at time $t+1$, i.e., $I_{h,t+1}$. Specifically, investments in the housing stock at time $t+1$ takes the following reduced form

$$I_{h,t+1} = L(p_{t+1}^h)^{\epsilon}, \tag{6}$$

where L is a fixed amount of new land made available every period, p_{t+1}^h is the house price in period $t+1$, and ϵ is the elasticity of housing investment with respect to the house price. The extent to which newly available land is turned into actual housing units is then given by $(p_{t+1}^h)^{\epsilon}$. The higher the price and the higher the elasticity, the more housing is made available. The aggregate housing stock, which includes both owned and rental housing, evolves according to

$$H_{t+1} = (1-\delta^h)H_t + I_{h,t+1}. \tag{7}$$

As the investment decision is made in the previous time period, this implies that the housing stock is perfectly inelastic in the period of an unexpected tax reform.[8]

The revenue from producing new housing capital $p_{t+1}^h I_{h,t+1}$ raises the question of how to distribute profits. We solve this issue by assuming that the government decides on a price per unit of land τ_{t+1}^{cf} at time t that the construction firm has to pay at time $t+1$. Similar to Favilukis et al. (2017), the price is set such that the expected profits of the construction firm is zero. As the firm's total costs are $\tau_{t+1}^{cf}L$, the price per unit of land that ensures zero profits is $\tau_{t+1}^{cf} = (p_{t+1}^h)^{1+\epsilon}$.

2.5 *Government*

The government runs a balanced pay-as-you-go (PAYG) retirement system, collects and redistributes bequests, and taxes the agents in a similar way as the U.S. tax system. The net tax revenues are spent on constant (wasteful) government expenditures G.

PAYG The payroll tax τ_t^{ss} adjusts to clear the PAYG system

$$\sum_{j=1}^{J} \Pi_j \mathbb{I}^w \int \tau_t^{ss} n_j(\mathbf{z}_j) l_j(\mathbf{z}_j)\, d\Phi(\mathbf{z}_j) = \sum_{j=1}^{J} \Pi_j (1-\mathbb{I}^w) \int \min\{\tau^{rr} n_{J_r}(\mathbf{z}_j), \bar{ss}\}\, d\Phi(\mathbf{z}_j), \tag{8}$$

[8]The law-of-motion for the housing stock can be used to find the fixed value of new land L. Without loss of generality, we set the house price p_{t+1}^h to one in the initial steady state. Since $p_t^h = p_{t+1}^h = 1$ and $H_t = H_{t+1} = H$ in steady state, L is equal to $\delta^h H$, i.e., the new land covers the depreciated housing stock.

where Π_j is the age distribution of households with $\sum_{j=1}^{J} \Pi_j = 1$ and Φ is the cross sectional distribution of the non-deterministic individual states at age j, i.e., $\mathbf{z}_j$. The left-hand side of equation (8) is the average payroll tax paid by all households. The right-hand side is equal to the average amount of pension benefits received by all households.

Bequests The government collects bequests in the form of deposits and housing net of mortgages from households who die and redistributes the funds to newborns and surviving households. The net amount collected at time t from a household that dies after age j is given by

$$\mathfrak{q}_{j,t}(\mathbf{z}_{j,t-1}) = (1+r_t)d'_{j,t-1}(\mathbf{z}_{j,t-1}) + (1-\varsigma^s-\delta^h)p_t^h h'_{j,t-1}(\mathbf{z}_{j,t-1}) \\ - (1+r_t^m)m'_{j,t-1}(\mathbf{z}_{j,t-1}).$$

The first term states that the government receives deposits plus any interest. The second term reflects the net amount received in terms of housing. Specifically, the government needs to pay the maintenance cost of the house before it sells the house and incurs the transaction cost of doing so. The last term shows that the government pays off any outstanding mortgages including interest. The total net amount collected is then

$$\mathfrak{q}_t = \sum_{j=1}^{J} \Pi_j (1-\phi_j) \int \mathfrak{q}_{j,t}(\mathbf{z}_{j,t-1})\, d\Phi(\mathbf{z}_{j,t-1}). \tag{9}$$

Part of these bequests are distributed to newborns to match the distribution of wealth among young households in the data, and to capture the positive correlation between wealth and earnings. A newborn household has initial assets $a_{1t}(\mathbf{z}_{1t})$, where the index 1 indicates period $j=1$. The remainder of the collected bequests is given to households that are still alive. Recall that bequests received are $a_{j,t}(\mathbf{z}_{j,t}) = \gamma_t w_t n_{j-1}(\mathbf{z}_{j,t})$ for $j \in \{2, ..., J_r\}$ and $a_{j,t}(\mathbf{z}_{j,t}) = \gamma_t y_{j,t}(\mathbf{z}_{j,t})$ for $j \in \{J_r+1, ..., J\}$. The parameter γ_t adjusts such that

$$\mathfrak{q}_t = \sum_{j=1}^{J} \Pi_j \int a_{j,t}(\mathbf{z}_{j,t})\, d\Phi(\mathbf{z}_{j,t}), \tag{10}$$

where $\mathfrak{q}_t$ is given by equation (9).

Taxes and expenditures Total government expenditures G are given by the government's tax revenues from households, the financial intermediary, and the construction firm as follows

$$G = \sum_{j=1}^{J} \Pi_j \int \Gamma_{j,t}(\mathbf{z}_{j,t})\, d\Phi(\mathbf{z}_{j,t}) + \tau_t^h p_t^h H_{f,t-1} + \tau_t^{cf} L, \tag{11}$$

where taxes $\Gamma_{j,t}(\mathbf{z}_{j,t})$ paid by households are

$$\Gamma_{j,t}(\mathbf{z}_{j,t}) = \tau_t^k r_t d_{j,t}(\mathbf{z}_{j,t}) + \tau_t^l y_{j,t}(\mathbf{z}_{j,t}) + T(y_{j,t}(\mathbf{z}_{j,t})) + \tau_t^c c_{j,t}(\mathbf{z}_{j,t}) + \tau_t^h p_t^h h_{j,t}(\mathbf{z}_{j,t}).$$

Property taxes paid by the financial intermediary $\tau_t^h p_t^h H_{f,t-1}$ are levied on the rental stock bought by the financial intermediary in period $t-1$. Across policy reforms, where we consider different property tax rates τ_t^h, the tax on capital income τ_t^k adjusts to ensure that the revenues equal government expenditures.[9]

2.6 *Resource constraint*

An aggregate resource constraint ensures that the agents in the economy do not spend more than what is available to them

$$C_t + G + K_{t+1} + \Omega_t \leq Y_t + (1-\delta^k)K_t, \tag{12}$$

where C_t is aggregate consumption, G is government expenditures, K_t is capital at the start of period t, Y_t is total output, and Ω_t is the sum of the transaction costs related to buying and selling houses as well as the intermediation costs of mortgages and those related to the rental business. The aggregation of key variables and market-clearing conditions are provided in Supplemental Appendix C. A formal equilibrium definition is relegated to Supplemental Appendix D.

3. Calibration

3.1 *Independently calibrated parameters*

Table I shows the full set of parameters that are based on estimates from the literature or that are computed directly in the data.

Demographics Households enter the economy at the age of $23-25$ ($j=1$). The last working period corresponds to the age group $62-64$ ($J_r=14$), and we assume that no household can live beyond the age group $80-82$ ($J=20$). The probability of dying between any two periods j and $j+1$, i.e., ϕ_j is computed using the Life Tables for the U.S. social security area 1900-2100 (see Bell and Miller (2005)). Specifically, we use the observed and projected mortality rates for males born in 1950.

Endowments and labor earnings The parameters related to labor productivity are based on the estimated earnings process in Karlman et al. (2021), which is estimated using data from the U.S. Bureau of Labor Statistics (BLS) and the Panel Study of Income Dynamics (PSID) (BLS, 2020a,b, PSID, 2017). Specifically, we take the deterministic life-cycle profile of productivity g_j to be the deterministic life-cycle *earnings* in their paper. The other parameters need some adjustments before they can be used. The income process in Karlman et al. (2021) is assumed to consist of a household fixed effect, a transitory shock, and a permanent shock, whereas in this paper, we assume that productivity follows an AR(1) process with an initial shock and a persistent shock. We set the persistence parameter ρ such that the variance of log productivity is increasing roughly linearly up until retirement. We let σ_ν^2 and σ_ξ^2 adjust such that the variance of log productivity for

[9]For robustness, we also consider changes in the tax on labor income τ_t^l or consumption τ_t^c, such that the total tax revenues always equal G.

the age group $47-49$ and the variance of log productivity for the age group $23-25$ are the same for the two processes. The age group $47-49$ was chosen since this is the period with the highest labor productivity.

Following Díaz and Luengo-Prado (2008), the replacement rate for retirees τ^{rr} is 50 percent. The maximum allowable benefit during retirement $\bar{ss}$ is calculated using data from the Social Security Administration (SSA) and corresponds to around 61 percent of average earnings for working-age households. The retirement benefits scale with w_t as shown in Section 2.1, which means that the benefits received by retirees move with the wage level.

The initial asset holdings for households a_1 are calibrated as in Kaplan and Violante (2014). We divide households aged 23-25 in the 1989 - 2013 waves of the Survey of Consumer Finances (SCF) into 21 groups based on their earnings (SCF, 2023). For each of these groups, we calculate the share with asset holdings above 1,000 in 2013 dollars and the median asset holdings conditional on having assets above this limit. The median asset value for each group is scaled by the median earnings among working-age households (23-64) in the SCF data. For model purposes, we rescale these asset values with the median earnings of working-age households in our model. Since the initial assets are scaled by earnings, they move with changes in the wage level.

Preferences The equivalence scale e_j is equal to the square root of the predicted values from a regression of family size on a third-order polynomial of age. Predicted values are obtained by using data from the PSID for the years 1970-1992 (PSID, 2017). In the benchmark model, we set the coefficient of relative risk aversion σ to 2, and the Frisch elasticity parameter φ to 0.67, which are standard values in the literature.

Houses The transaction costs of buying and selling a house are taken from Gruber and Martin (2003), who estimate these costs to around 2.5 and 7 percent of the house value, respectively. Based on data from the Bureau of Economic Analysis (BEA), covering the years 1989-2013, we set the depreciation rate of owned housing to 2.3 percent. Similar to Kaplan et al. (2020), we set the elasticity of housing investment with respect to the house price ϵ to 1.5.

Mortgages The minimum down-payment requirement when purchasing a house or increasing an existing mortgage is set to 0.2 of the house value, which is a standard value in the literature. We choose a yearly spread for mortgages κ of 0.01. This is approximately the spread between the contract rate on 30-year fixed-rate conventional home mortgage commitments and market yields on the 30-year constant maturity nominal Treasury securities over the period 1997 to 2015.

Taxes The initial consumption tax rate τ^c is set to 7 percent, which is the population-weighted average state and local sales tax across U.S. states in 2021 (The Tax Foundation, 2013a). Following Trabandt and Uhlig (2011), we let the initial capital-income tax rate τ^k be 0.36. This is broadly in line with what papers in the optimal capital taxation literature are using. Acikgöz et al. (2018), Davis and Heathcote (2005), Domeij and Heathcote (2004), and İmrohoroğlu (1998) all used a capital-income tax rate in the range of

$0.36-0.4$. The linear labor-income tax τ^l is a tax that we only use to balance the government's budget in some of the experiments where we alter the property tax. It is therefore set to zero in the baseline economy. The key tax rate in this paper is the property tax τ^h, which is 0.01 in the initial economy. This is based on data from the 2013 American Housing Survey (AHS), which shows that the median amount of real estate taxes per $\$1,000$ of housing value is approximately 10 dollars.[10]

Production The interest rate in steady state r is equal to the rental rate of total capital R^T less the depreciation of total capital δ^T. Assuming a Cobb-Douglas production function for the total economy, the rental rate is equal to $(Y^T/K^T)\alpha_k^T$, where Y^T is the gross domestic product (GDP) less investments in defense-related capital. K^T includes all non-defense capital, i.e., both residential and nonresidential capital, and α_k^T is the capital-income share for total capital K^T, which we assume to be $1/3$. Using data from the BEA for the years $1997-2013$, the rental rate of total capital R^T is 0.117 on average. The depreciation rate δ^T is 0.051 and is computed as the depreciation of total capital divided by total capital. Taken together, the values for the rental and depreciation rates imply an interest rate of 0.066.

To compute δ^k, the depreciation rate for business capital, we divide the depreciation of nonresidential capital by the stock of nonresidential capital. This gives a yearly depreciation rate of 0.067. The capital-income share α_k for business capital is computed as $R^N K^N/Y^N$, where $R^N = r + \delta^k$ is the rental rate of nonresidential capital, K^N is nonresidential capital, and Y^N is GDP (Y^T) less consumption of housing services. We assume that the return net of depreciation r is the same for all capital types. Then, the capital-income share is 0.265.

Normalizations Let us also discuss the normalizations, as these relate to how the model is solved.[11] The house price is normalized to one in steady state. The long-run supply of housing is then equal to the long-run demand of housing at this price. Aggregate productivity A can be computed using the expressions for the interest rate in equation (3) and the wage level in equation (4). First, solve for K_t/N_t in equation (3), and substitute into equation (4). Second, impose the normalization $w_t = 1$ and solve for A to get

$$A = \left(\frac{1}{1-\alpha_k}\right)^{1-\alpha_k}\left(\frac{r+\delta^k}{\alpha_k}\right)^{\alpha_k}.$$

With our calibrated values of α_k, r, and δ_k, A is equal to 1.4.

3.2 *Internally calibrated parameters*

The model is calibrated to match salient features of the U.S. economy. Table II shows parameters internally calibrated by simulation, along with a comparison between data and model moments. Unless otherwise stated, we use data from the SCF, pooled across

[10]See table C-10-OO in the 2013 American Housing Survey.

[11]The computational method to solve the model is similar to the one in Karlman et al. (2021).

TABLE I. Independently calibrated parameters, based on data and other studies

Parameter	Description	Value
Demographics		
$j=1$	Newborn households	1 (ages 23-25)
J_r	Last working period	14 (ages 62-64)
J	Last possible period alive	20 (ages 80-82)
ϕ_j	Survival probability	Bell and Miller (2005)
Endowments and labor earnings		
g_j	Deterministic labor productivity	Karlman et al. (2021)
ρ	Persistence of prod. shock	0.995
σ_ν^2	Var of persistent prod. shock	0.035
σ_ξ^2	Var of initial prod. shock	0.119
τ^{rr}	Replacement rate retirees	0.5
$\bar{ss}$	Maximum benefit retirement	See text
a_1	Initial assets	Kaplan and Violante (2014)
Preferences		
e_j	Equivalence scale	See text
σ	Coefficient of relative risk aversion	2
φ	Frisch elasticity	0.67
Houses		
ς^b	Transaction cost buying house	0.025
ς^s	Transaction cost selling house	0.07
δ^h	Depreciation, housing	0.023
ϵ	Elasticity of housing investments	1.5
Mortgages		
θ	Down-payment requirement	0.20
κ	Yearly spread, mortgages	0.01
Taxes		
τ^c	Consumption tax	0.07
τ^k	Capital-income tax	0.36
τ^l	Linear labor-income tax	0
τ^h	Property tax	0.01
Production		
r	Interest rate	0.066
δ^k	Depreciation, capital	0.067
α_k	Capital-income share	0.265
Normalizations or implied values		
p^h	House price	1
w	Wage rate	1
A	Aggregate productivity	1.4
K/Y	Capital-output ratio (productive capital)	1.99
H/Y	House value-to-output ratio	2.00
G/Y	Government consumption-to-output ratio	0.17

Note: The values are annual for the relevant parameters. When solving the model, we adjust these values to their three-year (one model period) counterparts.

TABLE II. Internally calibrated parameters

Parameter	Description	Value	Target moment	Data	Model
Preferences					
α	Consumption weight in utility	0.86	Median house value-to-earnings	2.34	2.32
υ	Utility shifter of bequest	6	Mean net worth age 80 - 82 over mean all ages	1.25	1.26
$\bar{q}$	Luxury parameter of bequest	1	Homeownership rate age 74 - 82	0.81	0.87
Houses					
$\underline{\mathrm{h}}$	Minimum owned house size	39	Homeownership rate	0.67	0.66
η	Intermediation cost, rentals	0.01	House price-to-rent ratio	11	11
Taxes					
λ	Level, earnings tax	1.87	Average marginal tax rate, working age	0.13	0.13
τ^p	Progressivity, earnings tax	0.17	Marginal tax rate distribution	See text	
Equilibrium objects					
β	Discount factor	0.95	Asset market clearing	See text	
μ	Disutility parameter of labor	0.03	Labor market clearing	See text	
τ^{ss}	Social security tax	0.13	Social security system clearing	See text	
γ	Bequest rate	0.11	Bequest clearing	See text	

Note: Parameters calibrated either by simulation or as the result of equilibrium conditions. The third column shows the resulting parameter values from the estimation procedure. The values are annual when applicable. When simulating the model, we adjust these parameter values to their three-year (one model period) counterparts. The fifth column presents the values of data moments that are targeted. The last column shows the model moments that are achieved by using the parameter values in column three.

survey years 1989 to 2019 (SCF, 2023). We restrict the sample to the bottom 99 percent of the distribution in terms of net worth, as the model is not set up to explain the accumulation of wealth at the very top.

Preferences The parameter α determines the weight on consumption and housing services in the utility function. This parameter is disciplined by targeting the median house value relative to earnings, conditional on owning a house. The strength of the bequest motive υ affects how much households dissave in the later parts of life. We therefore calibrate it by targeting the mean net worth at the oldest age in the model, which corresponds to age 80 to 82, relative to the mean net worth at all ages (age 23 to 82). The bequest parameter that determines the extent to which bequests are luxury goods $\bar{q}$, affects the homeownership rate among older households. To calibrate this parameter, we target the homeownership rate among the three oldest ages in the model, i.e., age 74 to 82.

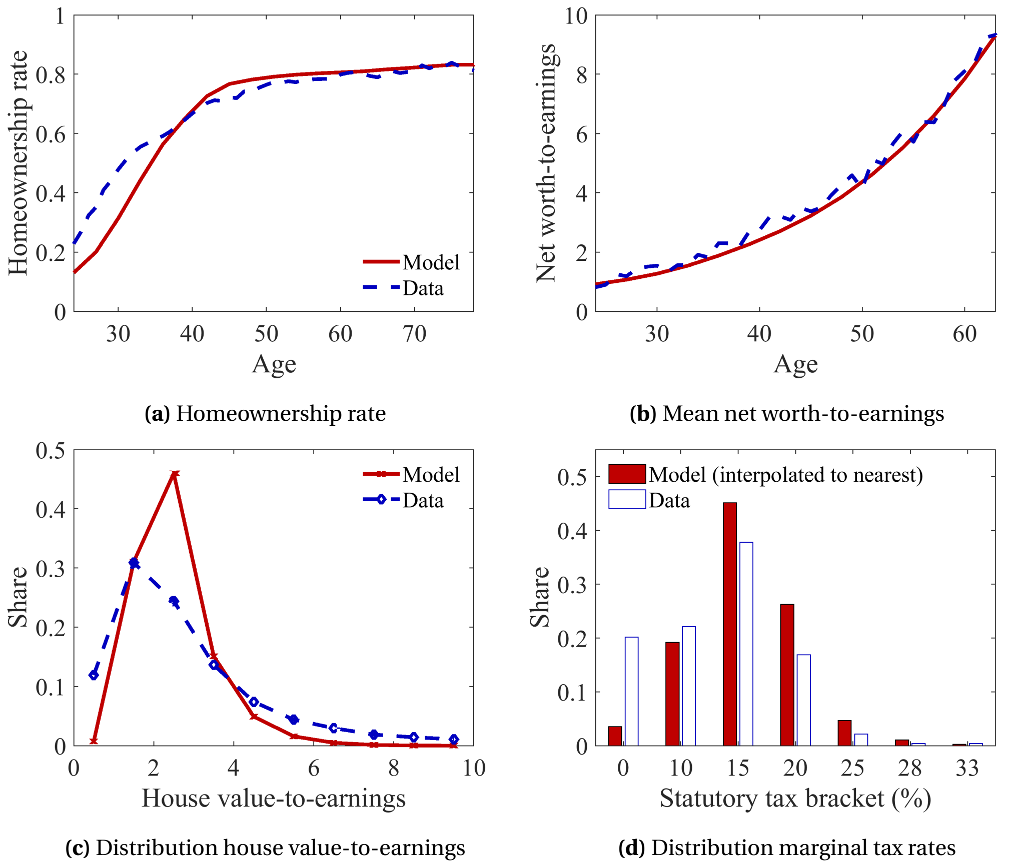
Houses The minimum owner-occupied house size $\underline{\mathrm{h}}$ is calibrated to match the overall homeownership rate in the data. The resulting value corresponds to roughly twice the average annual earnings for working-age households in the model. The intermediation cost of rental housing η is set from equation (5) to match the house price-to-rent ratio of 11 in the data. Garner and Verbrugge (2009) find a price-to-rent ratio of 12, whereas U.S. Census Bureau (2005) documents that the median rental receipts relative to value is 11 percent.

Taxes The level parameter λ of the progressive earnings tax function is disciplined by targeting the average marginal tax rate among the working age population. The parameter that determines the degree of progressivity τ^p is set to minimize the sum of the absolute differences between the fractions of households at different statutory tax brackets in the data and in the model. In the model, households are allocated to their nearest bracket for this computation. The data is from the Congressional Budget Office and the Tax Foundation for the years 2003 to 2012 (Harris (2005) and The Tax Foundation (2013b)).

Equilibrium objects The equilibrium objects in the model are the interest rate r_t, the wage rate w_t, the house price p_t^h, the social security tax τ_t^{ss}, and the bequest rate γ_t. In the initial steady state, we take the value of r from the data as described above and calibrate the discount factor β to ensure that the supply of business capital K_f equals business capital demand K. In all other steady states and in the transitions, the discount factor is held constant, and the interest rate varies to clear the capital market. As mentioned above, in the initial steady state, the wage rate and the house price are normalized to one, but we let these prices adjust in the counterfactual experiments so that the labor market and the house market clear. The parameter that determines the disutility of labor is set such that the aggregate labor supply is equal to aggregate labor demand, which is normalized to one in the initial steady state. The social security tax is the rate that makes sure the social security system is in balance, see equation (8). Finally, the bequest rate γ is the solution to the bequest scheme given by equation (10).

3.3 *Model versus data*

To validate the model performance, Figure 1 presents a comparison of model outcomes with the data, for key variables of the analysis. Since we focus on changes in property taxes, and also consider changes in capital-income taxes, labor-income taxes, and consumption taxes, it is important that the model matches the data in terms of the importance of housing relative to other financial wealth and relative to earnings. Additionally, the paper studies heterogeneous effects of changing the property tax. Hence, it is preferable that the model captures the heterogeneity in the population along these variables as well. We therefore compare life-cycle and cross-sectional moments computed in the model with their counterparts in the data. In Figure 1a and 1b we see that the model produces homeownership rates and net worth relative to earnings over the life cycle that are well aligned with the data. Moreover, the distribution of house values relative to earnings captures well the heterogeneity in the U.S. population, as seen in Figure 1c. Additionally, the progressive earnings tax function allows us to match the distribution of households exposed to different marginal labor-income tax rates in the data fairly well, see Figure 1d. The model is worse equipped to match mortgage balances in the data. Over the past ten-year period, the 75th percentile of LTVs at origination in the data ranged from 80 to 88 percent, whereas the 75th percentile of LTVs among first-time buyers in the model is 30 percent (FRED, 2024). In order to match aggregate data on mortgages as well as net worth and housing wealth, additional heterogeneity among households in terms of discount rates or rates of return on other assets would be needed.



(a) Homeownership rate

(b) Mean net worth-to-earnings

(c) Distribution house value-to-earnings

(d) Distribution marginal tax rates

FIGURE 1. Comparison of model and data

Note: Figure 1a shows the share of homeowners at each age, and Figure 1b plots the mean net worth-to-earnings for each age, restricted to non-retired households with annual earnings larger than 12,000 dollars. Figure 1c divides homeowners into ten bins according to their house value-to-earnings and illustrates the share of households in each bin. The markers show the mid-points of each bin. Figure 1d shows the fractions of taxpayers facing different marginal tax rates. For the model, households are allocated to their nearest statutory bracket for illustration purposes. The data in Figure 1a - 1c are from the SCF, pooled across survey years 1989-2019 (SCF, 2023). The data in Figure 1d is from Harris (2005). Model refers to the baseline economy with a property tax rate of one percent.

4. OPTIMAL PROPERTY TAX IN THE LONG RUN

This section studies optimal taxation in steady state, i.e., without considering the impact on current generations and the transition to a new steady state. This is a natural starting point for several reasons. First, a social planner is likely to assign some weight to future generations. In the limit, as the social discount factor approaches 1, the welfare consequences for newborns in the long run dominate. For these newborn generations, the optimal policy is given by the optimal steady-state reform. Second, to understand why short-run welfare effects differ from those in steady state, it is helpful to investigate the factors determining the welfare effects in steady state. Section 5 builds on these insights and explores the costs and benefits of property taxation once the dynamics are accounted for.

4.1 *Welfare measure and planner problem*

In order to compare steady-state policies, we need an interpretable measure of welfare. There are two challenges when choosing a suitable welfare measure. First, one needs to decide how to measure individual welfare. Second, individual welfare must be aggregated to a measure of societal welfare. This aggregation is non-trivial as households differ in many respects.

We measure individual welfare as the constant consumption stream that is equivalent to a household's ex-post value function. To be more concrete, let the value function $V_i(\tau^h)$ for newborn i under a policy with the property tax rate τ^h be

$$V_i(\tau^h) \equiv \sum_{j=1}^{J} \left(\beta^{j-1} \prod_{k=1}^{j-1} \phi_k \right) \left[U_j \left(c_{i,j}(\tau^h), s_{i,j}(\tau^h), l_{i,j}(\tau^h) \right) + \beta(1-\phi_j) U^B \left(q'_{i,j}(\tau^h) \right) \right],$$

where $c_{i,j}(\tau^h)$, $s_{i,j}(\tau^h)$, $l_{i,j}(\tau^h)$, and $q'_{i,j}(\tau^h)$ are the realized values of consumption, housing services, amount worked, and net worth of household i at age j under policy τ^h. Moreover, $\beta^{j-1} \prod_{k=1}^{j-1} \phi_k$ is the effective discount factor for streams of utility at age j from the perspective of a newborn. Next, let $\omega_i(\tau^h)$ capture individual welfare in consumption equivalents under policy τ^h. Specifically, $\omega_i(\tau^h)$ is the constant consumption stream for individual i such that

$$V_i(\tau^h) = \sum_{j=1}^{J} \tilde{\beta}^j \frac{\omega_i(\tau^h)^{1-\sigma}}{1-\sigma}, \tag{13}$$

where households' effective discount factor is $\tilde{\beta}^j \equiv e_j \beta^{j-1} \prod_{k=1}^{j-1} \phi_k$.

We aggregate individual welfare $\omega_i(\tau^h)$ as follows

$$\left(\int_0^1 \omega_i(\tau^h)^{1-\hat{\sigma}} \, \mathrm{d}i \right)^{\frac{1}{1-\hat{\sigma}}}, \tag{14}$$

where the desire to redistribute is given by the planner's inequality aversion $\hat{\sigma}$. The higher is $\hat{\sigma}$, the higher is the desire to redistribute. This welfare measure allows for a clear mapping between individual welfare and aggregate welfare. The main aggregate measure that we consider is utilitarian welfare, by assuming that $\hat{\sigma}$ equals households' risk aversion σ.[12]

The planner problem is to choose τ^h to maximize (14) subject to a series of restrictions. First, the government constraint (11) needs to hold. As government spending G is assumed to be fixed, we let the tax on capital income τ^k adjust to ensure that the government's net revenues equal G. We also consider two alternative revenue-neutral policies where the labor-income tax τ^l or the consumption tax τ^c adjust instead, to clear the government's budget. Second, we consider competitive equilibria, where the interest rate adjusts to ensure that capital demand equals capital supply; the wage rate adjusts to

[12] In Supplemental Appendix B, we show why utilitarian welfare takes this specific form. In Supplemental Appendix E.5, we show the main results if instead considering aggregate economic efficiency, i.e., $\hat{\sigma} = 0$.

clear the labor market, and the house price ensures that housing demand equals housing supply.[13] Third, the bequest parameter γ adjusts such that the amount of bequests left equals the amount received by households. Finally, the social security tax ensures that this system is in balance.

4.2 *Quantitative results in steady state*

There are a two main aspects of property taxation that complicates a theoretical formulation of the optimal tax rate. First, since housing is both an asset and provides services to households, the taxation of property does not only affect the relative tax treatment of housing capital as opposed to business capital, but also the tax wedge between housing and non-housing consumption. Since there are both capital-income taxes and consumption taxes in the U.S., it is not clear what weight one should assign to the respective tax wedges, when considering a change in the property tax. Second, there are significant frictions in the U.S. housing and financial markets. When accounting for incomplete markets, many theoretical results of optimal taxation do not need to hold. Specifically, if a financial friction is severe, taxation that reduces the importance of the friction can lead to significant benefits. To address these challenges, we use the quantitative incomplete-markets framework described in the previous sections to compute the optimal property tax rate, taking as given the current U.S. tax system. Since there are many potential tax distortions in place, the optimal property tax that we compute is not necessarily a result of eliminating a given distortion, but reducing distortions associated with multiple tax wedges and frictions, which can be affected implicitly by the pairwise tax adjustments that we consider.

As a starting point it is still useful to contemplate potential distortions in the current tax system. For the experiments that we consider, there are two main distortions that are directly affected. First, there is a difference in the tax treatment of housing capital and business capital, which creates an intertemporal distortion.[14] In the baseline economy, housing capital is subject to the 1 percent property tax, whereas the income of business capital is taxed at a rate of 36 percent. These are not directly comparable in our setting, but in a frictionless model one can show that a property tax needs to be equal to the capital-income tax times the interest rate, i.e., approximately 2.4 percent in the current setting, for an equal treatment of the two types of capital.[15] Hence, housing capital receives a preferential tax treatment relative to business capital in the current tax code.

[13]In Supplemental Appendix E.2 we consider the case with fully elastic supply of housing, such that house prices are fixed.

[14]There is a rich literature that documents that there is a preferential tax treatment of housing in the U.S., see, e.g., Gervais (2002). The main tax benefit of housing is that imputed rent for homeowners is not taxed. Historically, mortgage interest deductibility added another tax advantage of owned housing relative to rental housing, but after the Tax Cuts and Jobs Act in 2017, less than 10 percent claim itemized deductions (Internal Revenue Service, 2024). Although taxing imputed rent could remove the tax wedge between housing and business capital, the same tax rate would not necessarily remove the intratemporal distortion. Moreover, there are practical challenges to implementing an imputed-rent tax, which might be one of the reasons why property taxes are more common.

[15]This holds in a model without financial frictions and intermediation costs, where all households own their home.

Second, there are intra-temporal distortions resulting from the differences in tax treatment of consumption, housing services, and leisure. The average consumption tax in the U.S. is 7 percent, whereas housing services are taxed indirectly through the property tax, which corresponds to approximately an 11 percent tax on housing services, if again considering a frictionless model. Leisure, on the other hand, is negatively taxed through the progressive labor-income tax and payroll tax, where the average marginal tax rate on labor income is 13 percent. Taken together, it is ex-ante not obvious what the optimal level of the property tax is, or even if it is higher or lower than the current level.

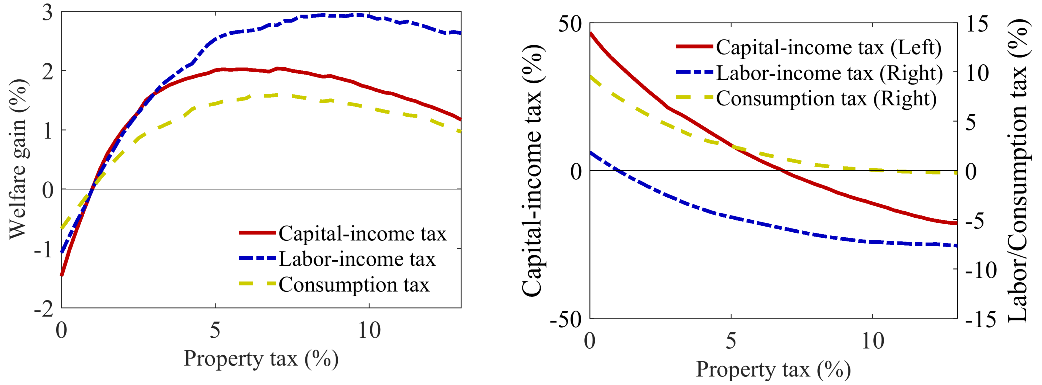
We find that the optimal steady-state property tax is much higher than the current level of 1 percent. In Figure 2a we see that the optimal property tax is approximately 7 percent in our baseline experiment where the tax on capital income is changed to clear the government's budget. Figure 2b shows that this translates into a capital-income tax of approximately -1 percent. We also find that the potential welfare gains are large. The scenario with the optimal property tax entails almost a 2 percent increase in the average of consumption equivalents, relative to the current tax system.

Table III compares aggregate variables and prices between the initial economy and the optimal steady state. In column four, we see that when the optimal property tax is implemented, and the capital-income tax is decreased, there is a considerable reallocation of capital. The aggregate level of business capital is significantly higher, whereas the housing stock is much reduced. This reallocation of capital increases output by 7 percent, and the new equilibrium is also associated with higher consumption. In terms of prices, the interest rate is reduced, as the capital stock is substantially larger. As the marginal product of labor increases, wages are higher, and the aggregate labor supply is slightly reduced. The higher property tax causes house prices to decline, which puts downwards pressure on rental rates. However, in equilibrium, rental rates are higher, as the provider of rental housing needs to be compensated for its higher costs from property taxes.

Why does taxing housing capital disproportionally more than business capital improve welfare? First, a distinguishing feature of housing capital is that it is not only a means of saving, but it also provides instantaneous utility to households. As a result, the demand for saving in housing is relatively inelastic as compared to the demand for saving in deposits, making a property tax less distortive than a capital-income tax. This can be seen if we conduct two simple experiments in partial equilibrium. If we impose a property tax that is one percent higher, i.e., $\tau^h = 0.0101$, the demand for housing decreases by 0.11 percent. If we instead increase the capital-income tax by one percent, i.e., $\tau^k = 0.3636$, the demand for deposits decreases by 1.04 percent.[16]

Second, the supply of housing is also relatively inelastic. This elasticity is important for quantifying the optimal property tax. The more a higher property tax distorts the use of housing services, the lower is the optimal tax rate. In Supplemental Appendix E.2, we consider two alternative settings where the housing supply is either fully elastic or less elastic than in our baseline calibration. In the first scenario, with fully elastic supply, the

[16]Although the capital-income tax is a tax on a flow this exercise is equivalent to increasing a comparable tax on the capital stock by one percent, since the capital-income tax is proportional to the stock of deposits.



(a) Welfare changes (%), newborns **(b)** Revenue-neutral policies (%)

FIGURE 2. Optimal taxation in steady state

Note: Figure 2a shows welfare changes in percent for newborns across different property tax rates. The current property tax rate in the U.S. is 1 percent. Figure 2b shows the tax rates on capital income, labor income, or consumption, that are needed to keep government expenditures G constant.

TABLE III. Key aggregate variables: initial vs optimal steady states

		Initial economy	Optimal steady-state, when altering tax on: Capital income	Labor income	Consumption
Property tax (%)		1.00	7.00	9.50	6.25
Capital-income tax (%)		36	-0.9	36	36
Labor-income tax (%)		0	0	-7.1	0
Consumption tax (%)		7.4	7.4	7.4	1.6
Normalized variables					
D:	Deposits	1	1.39	1.25	1.15
K:	Capital	1	1.32	1.22	1.12
N:	Labor supply	1	0.98	0.98	0.98
H:	Housing stock	1	0.75	0.71	0.76
$p^h H$:	Value of housing stock	1	0.62	0.57	0.64
Y:	Output	1	1.06	1.05	1.03
C:	Consumption	1	1.04	1.03	1.02
p^h:	House price	1	0.83	0.80	0.84
p^r:	Rental price	1	1.15	1.32	1.17
w:	Wage level	1	1.08	1.06	1.03
Other variables					
r:	Interest rate (%)	6.60	4.30	4.86	5.56
$\bar{r}$:	Interest rate after tax (%)	4.32	4.34	3.16	3.63
r^m:	Mortgage interest rate (%)	7.60	5.34	5.89	6.58

Note: For illustration purposes, all values, except for the interest rates and the tax rates, are normalized to one for the initial steady state.

aggregate housing stock falls significantly more than in the baseline for a given increase in the property tax rate. As an example, if the property tax is increased to 7 percent, the housing stock decreases by 25 percent in the baseline and 42 percent when supply is fully elastic. The optimal property tax rate is approximately 4 percent with fully elastic supply, which is significantly lower than the 7 percent in our baseline calibration, but still notably higher than the current level of 1 percent. Hence, the optimal property tax is 3 percentage points higher due to that housing supply is not fully elastic. In the second

TABLE IV. Decomposition of welfare effects (%)

		Capital income	Labor income	Consumption
Optimal steady state		2.0	2.9	1.6
Only changing:				
	Property tax	-5.1	-6.4	-4.6
	Alternative tax (τ^k, τ^l, or τ^c)	3.0	5.5	3.6
	Wage rate	5.2	3.8	2.2
	House price	4.8	6.5	4.4
	Interest rates	0.2	0.1	-0.0

Note: The first row presents the steady-state welfare effects, in percent, for the three optimal property tax scenarios: when either the tax on capital income, labor income, or consumption is changed to clear the government's budget. The following rows decompose the total welfare results by showing the welfare effects from deviating from the initial steady state by only changing one tax or price at a time to their values in the optimal steady state. In all experiments, the rent is endogeneous.

scenario, on the other hand, with a less elastic housing supply ($\epsilon = 1.0$ instead of 1.5), the property tax distorts the use of housing services to a smaller extent. In this case the aggregate housing stock is reduced by 20 percent if the property tax is increased to 7 percent, and the optimal property tax is higher than in the baseline.

Finally, to understand the welfare effects we also need to understand how the tax policy affects how constraining the various frictions are. Performing a simple back-of-the-envelope computation of welfare by feeding in the changes in aggregate consumption, housing, and labor from Table III into the utility function suggests an increase in welfare of approximately 1 percent. Since the average effects cannot explain the full welfare gain, distributional effects must be important in explaining the results. Since markets are incomplete, the permanent-income hypothesis does not hold, and especially young households are constrained in their spending. A change in tax policy that allows for an improved life-cycle consumption smoothing is therefore preferred.[17]

To understand where such a beneficial redistribution comes from, we decompose the welfare effects by conducting a number of partial-equilibrium exercises. Table IV shows the welfare effects if we deviate from the initial steady state by only changing one tax or price at a time, i.e., we impose each new tax rate or price from the optimal steady state, in isolation. The table reveals three important takeaways. First, increasing the property tax to the optimal higher level reduces welfare more than the welfare gain from decreasing the capital-income tax. Hence, equilibrium effects are indeed essential for understanding the total change in welfare. Second, the effect on house prices and wages are the largest contributors to the welfare gain. Third, although households are net savers in this economy, the reduced interest rates are not negative for welfare in the aggregate. This hints at lower rates having favorable redistributional consequences.

Figure 3a shows the average savings in deposits as well as housing over the life cycle. At first glance, it may seem reasonable to tax business capital higher and housing

[17] Welfare gains could also stem from redistribution from households with relatively high initial wealth or productivity to those who are relatively poor or less productive. This is not an important source of the welfare gains, since we find similar results when considering efficiency as compared to utilitarian welfare (see Supplemental Appendix E.5).

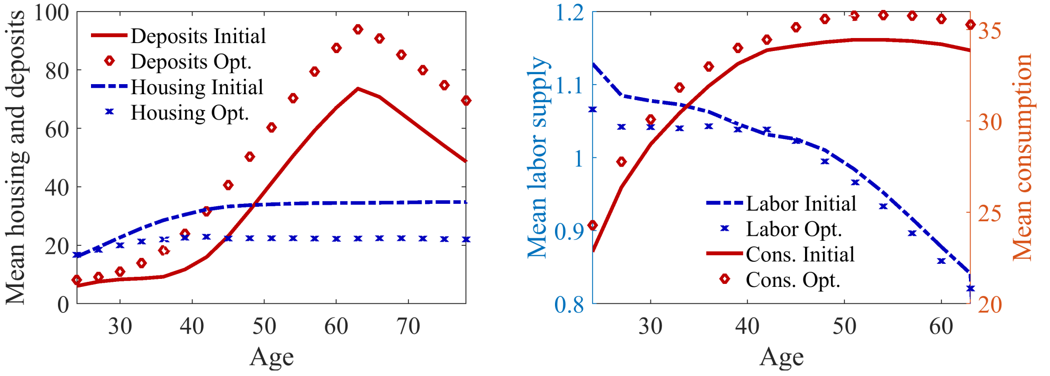
capital less, as savings in deposits are concentrated among the middle-aged, unconstrained households, whereas housing is more evenly spread across the life cycle. However, a higher tax on business capital actually worsens the situation for young households. A higher property tax, paired with a lower tax on business capital, on the other hand, causes a significant increase in aggregate deposits, as seen in the figure, which reduces equilibrium interest rates. Lower interest rates are particularly beneficial for the young since it lowers the cost of mortgages, whereas older households with substantial savings are negatively affected.

Figure 3b shows the life-cycle profiles of consumption and labor supply in the baseline economy as compared with the optimal steady state with a higher property tax. The optimal steady state is associated with higher consumption for all ages, but the relative increase is the largest for the young. Moreover, young households choose to work considerably less in the optimal steady state. Since young households expect their productivity and earnings to increase with age, they would like to borrow against their future income and work less early on. However, due to the borrowing constraint, they are constrained in their spending, have a high marginal utility of consumption, and consequently choose to work relatively hard. Hence, the flattening of the labor-supply curve over age is a clear signal of improved life-cycle profiles, where young households are less constrained.

It is not only the lower interest rates that lead to an improved consumption-smoothing over the life cycle, but lower house prices and higher wages also contribute. In Supplemental Appendix E.1 we show how these three equilibrium price changes influence the life-cycle profiles of consumption, housing services, and labor supply. The lower interest rates have the largest effect on the life-cycle profiles, partly due to intertemporal substitution. The lower house price also contributes to an improved smoothing of both housing services and consumption over age. The improved life-cycle profiles due to lower house prices are also reflected in a flattening of the labor-supply curve, such that the young reduce their hours worked whereas the old work more. Higher wages benefit households of all ages, by allowing for more consumption, housing, and less work, and the young are marginally more affected.

To summarize, there are three main reasons why a higher property tax is beneficial in the long run. First, the demand for housing capital is less elastic than the demand to save in deposits. Second, the supply of housing capital is also relatively inelastic. Third, the equilibrium effects on house prices, interest rates, and wages all contribute to an improved consumption smoothing over the life cycle. Higher property taxes reduce house prices and cause a reallocation of capital from housing to business capital, which lowers interest rates and increases wages.

Since the main focus of this paper is to study optimal property taxation, our baseline experiment is to consider which type of capital is best to tax: business capital or housing capital. This is a relatively clean experiment since it does not alter overall tax revenues, and importantly, it does not change the overall tax burden on saving. However, it is also useful to consider if the welfare improvements that we find are dependent on the tax that is used to clear the government budged when the property tax is altered. For robustness,



(a) Deposits and housing **(b)** Labor supply and consumption

FIGURE 3. Life-cycle profiles in the initial steady state vs the optimal steady state

Note: Life-cycle profiles of mean deposits, housing services, labor supply, and consumption, for the initial steady state with a property tax of 1 percent, as compared with the steady state with the optimal property tax of 7 percent and a capital-income tax of -0.9 percent.

we therefore consider adjusting the labor-income tax or the consumption tax, instead of the capital-income tax, in response to changes in the property tax rate.

Figure 2 shows that the optimal steady-state property tax is much higher than the current level regardless if we adjust the capital-income tax, the labor-income tax, or the consumption tax to clear the government budget. Importantly, in Table III, we see that the two alternative tax systems, where the optimal property tax is implemented, are also associated with considerable reallocations of capital. A clear pattern across the three experiments is that the aggregate level of business capital is significantly higher, whereas the housing stock is substantially reduced. Moreover, wages, output, and consumption are higher in all three scenarios, and labor supply is reduced.[18]

In the two alternative experiments, we find that the same mechanisms are at play as in the setting where the capital-income tax is reduced, explaining why a higher property tax is still optimal. Even though the capital-income tax is not reduced, it is still preferred to have a disproportionally higher tax on housing capital than business capital, as housing demand and supply are relatively inelastic. Furthermore, a higher property tax reduces house prices and causes a reallocation of savings from housing to deposits, lowering the equilibrium interest rate and increasing the wage rate. These price changes are especially beneficial for young households who want to borrow against their future higher income, leading to an improved life-cycle consumption smoothing.

Although there are many similarities across the three optimal property-tax scenarios, there are also differences. In the second experiment, where the labor-income tax adjusts to clear the government budget, the optimal property tax is 9.5 percent and the labor-income tax is reduced by 7.2 percentage points. These relatively large tax changes are also associated with the greatest aggregate welfare gains, as seen in Figure 2a. Table IV shows that the reduced taxation of labor income on its own contributes to the larger

[18] If considering more decimals in Table III, the labor supply responses are not identical. Labor supply is reduced by 2.21, 2.26, and 1.66 percent, in the respective experiments.

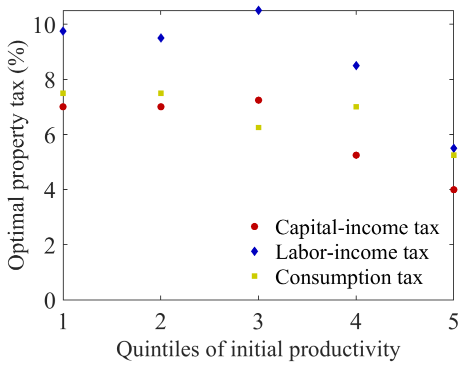


FIGURE 4. Optimal property tax rates (%) across initial labor productivity

Note: Initial labor productivity n_{i1} is the productivity of household i at age $j = 1$. Based on initial productivity, households are divided into quintiles and each marker shows the property tax rate that maximizes average individual welfare within the specific quintile.

welfare gain in this scenario. The lower labor-income tax reduces the intra-temporal distortions through a more equal tax treatment of consumption, housing services, and leisure. In the third experiment, the optimal property tax is 6.25 percent, which comes with a consumption tax that is reduced to 1.6 percent. The reduction of the consumption tax worsens the distortion between housing and non-housing consumption, and this scenario is associated with the lowest aggregate welfare gain. Furthermore, an important difference between the baseline and the two alternative experiments, is that the optimal property tax in the latter two implies an higher tax on saving, since the capital-income tax is not reduced to compensate for the higher property tax. That it is optimal with a higher tax on saving in these two experiments is in line with the findings in Conesa et al. (2009), who find that when life-cycle features are accounted for, saving is relatively inelastic, as households have a strong incentive to save for retirement. A higher tax on capital (housing capital, in our case) therefore has limited distortionary effects on the saving choice.

4.2.1 *Optimal property taxes across income* The optimal policies mask important heterogeneity across households. Figure 4 shows that households with higher labor income, illustrated by higher initial labor productivity n_{i1}, prefer a relatively lower property tax rate. The welfare of households at the bottom 20 percent of the distribution is maximized when the property tax is 7 to 10 percent, whereas the top 20 percent are best off when the property tax rate is 4 to 6 percent. Poorer households benefit from higher wages, lower interest rates, and the fall in house prices. Richer households also gain from higher wages and lower house prices but are more negatively affected by the lower return on savings. Moreover, high-income households are less eager to raise the property tax, since they reap larger benefits from the current tax system, which allows them to reduce their overall tax burden by investing in housing.

5. Winners and losers from property taxation when including transitional dynamics

In this section, we carefully consider the transitional dynamics following a tax reform. When accounting for transitional effects it is ex ante not clear that the optimal property tax should be considerably higher than today. First, it takes time to reallocate capital from housing to business capital. As a result, interest rates and wages do not adjust immediately to their new steady-state levels after a tax reform. Second, sudden changes to the tax system may not be appreciated by current generations, as they have made saving decisions under the assumption that property taxes would remain constant. For example, an increase in property tax payments is likely to affect homeowners negatively.

5.1 *Welfare measure and planner problem*

The planner problem is no longer confined to maximizing the welfare of newborns in the long run. The welfare measure also needs to consider the impact on current generations and the newborn generations that enter the economy along the transition to the new steady state. Let $\omega_{igt}(\boldsymbol{\tau^h})$ be the constant per-period consumption equivalent for household i in the g'th generation at time t under a certain policy $\boldsymbol{\tau^h} \equiv \{\tau_t^h\}_{t=1}^{\infty}$. In Supplemental Appendix B, we provide a detailed account of how the individual consumption equivalents are computed. To capture the consequences for all generations, the social welfare function takes the following form

$$\left(\sum_{g=1}^{J} \Lambda_{g1} \int_0^1 \omega_{ig1}(\boldsymbol{\tau^h})^{1-\hat{\sigma}} \, \mathrm{d}i + \sum_{t=2}^{\infty} \Lambda_{1t} \int_0^1 \omega_{i1t}(\boldsymbol{\tau^h})^{1-\hat{\sigma}} \, \mathrm{d}i \right)^{\frac{1}{1-\hat{\sigma}}}, \tag{15}$$

where the first term is the welfare of the generations alive at the time of a policy change and the second term captures the welfare of households that enter throughout the transition. Λ_{gt} is the weight assigned to the g'th generation at time t. For example, Λ_{21} is the weight assigned to the second generation alive in the first period of the transition and Λ_{12} is the weight assigned to a newborn generation in the second period of the transition. At any time t, the weight is higher for younger generations as they constitute a larger share of the population and because they expect to live longer. The weight assigned to each generation also depends on family size through the equivalence scale e_g. Moreover, a social discount factor Θ^{t-1} decides the weight of current generations relative to newborn generations at time t. The higher is the social discount factor, the higher is the weight on the welfare of future generations. A formal definition of Λ_{gt} is relegated to Supplemental Appendix B.2. Again, $\hat{\sigma}$ captures the inequality aversion of the planner. As in Section 4, we analyze optimal policies using a utilitarian welfare measure. In Supplemental Appendix B.2, we show how the utilitarian welfare can be represented by expression (15) when $\hat{\sigma} = \sigma$.

The planner problem is to choose a policy $\boldsymbol{\tau^h}$, i.e., a sequence of the property tax rate $\{\tau_t^h\}_{t=1}^{\infty}$ to maximize expression (15) subject to a number of constraints. In the main analysis, we consider once-and-for-all type of policies, which means that the property tax changes immediately to the new long-run level, i.e., $\{\tau_t^h\}_{t=1}^{\infty} = \tau_{\text{new}}^h \; \forall t$. The policies are assumed to be credible and unexpected.[19] The permanent one-time change of the property tax rate gives rise to a sequence of capital-income tax rates $\{\tau_t^k\}_{t=1}^{\infty}$, a sequence of the interest rate $\{r_t\}_{t=1}^{\infty}$, a sequence of the wage rate $\{w_t\}_{t=1}^{\infty}$, a sequence of the house price $\{p_t^h\}_{t=1}^{\infty}$, and a sequence of the bequest parameter $\{\gamma_t\}_{t=1}^{\infty}$. The capital-income tax rates ensure that the tax revenues exactly cover government expenditures G. The interest rate clears the capital asset market and the wage rate clears the labor market. The house price ensures that housing demand equals housing supply in all periods. Finally, the bequest parameter adjusts such that bequests received equal bequests collected.

5.2 *Permanent one-time changes in the property tax*

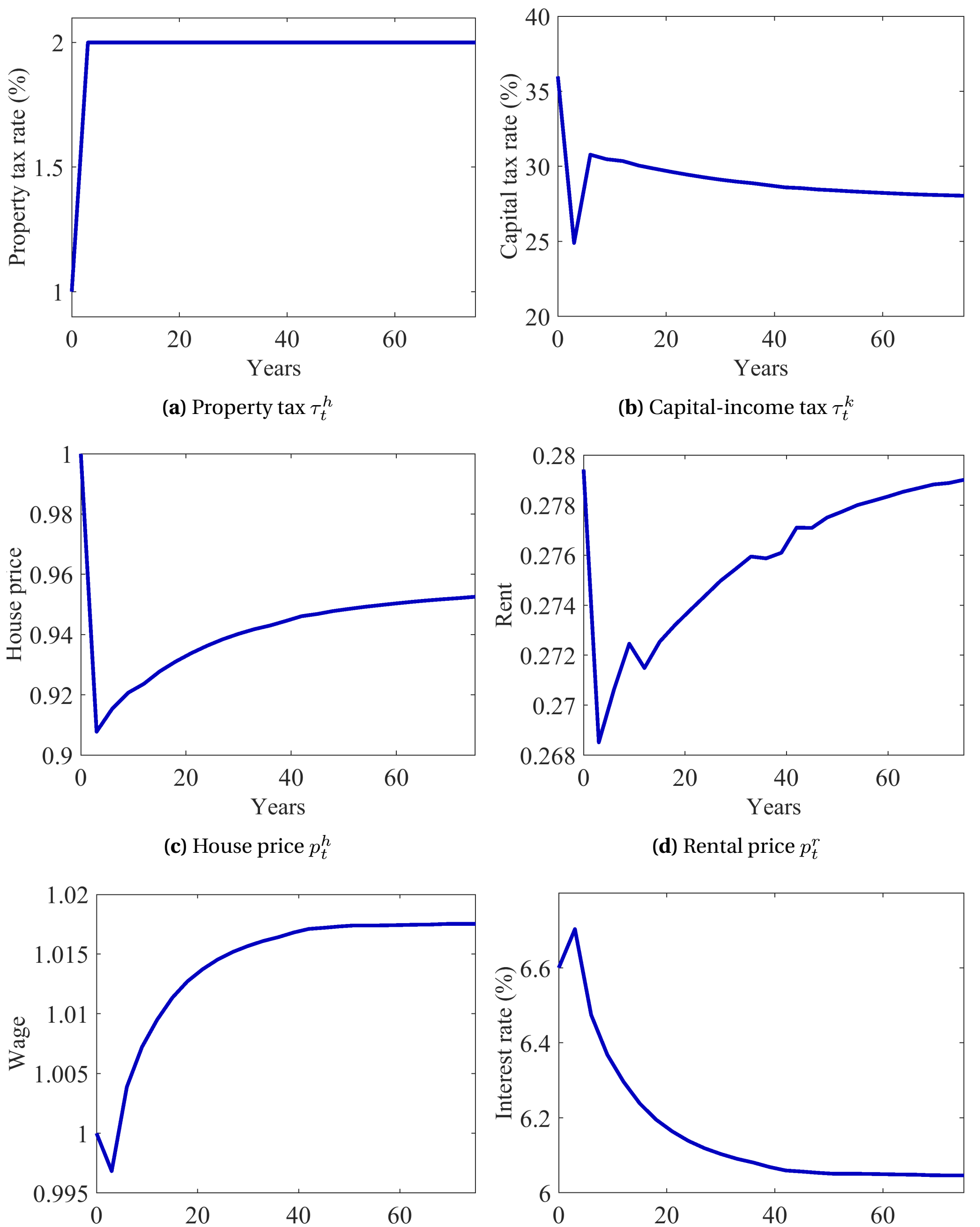
To analyze the transitional effects of increasing the property tax, we begin by considering an immediate and permanent doubling of the property tax from the current level of 1 percent to 2 percent. Figure 5 shows the equilibrium transition paths of several key variables. As evident, the short-run effects on prices and quantities of increasing the property tax are significantly different from the long-run effects.

Starting with the house price, Figure 5c shows an immediate fall to a level much lower than the new steady-state level. In fact, the initial drop is almost twice as large as the long-run reduction. Following the immediate house-price fall, there is a slow convergence back to the new long-run level. This pattern is quite intuitive. The higher property tax makes housing less attractive, causing an instantaneous reduction in housing demand. Housing supply, on the other hand, evolves more gradually since the housing stock at the time of the reform is predetermined. Consequently, the house price that clears the housing market is the lowest initially, and it slowly recovers as the housing stock declines over time. The rental rate, which is a function of the house price, shows a similar pattern, as illustrated in Figure 5d.

The transition paths of the capital-income tax rate, the wage rate, and the interest rate are slightly more involved. In Figure 5b we see that the capital-income tax falls on impact, before jumping up and then slowly converging downwards to its long-run level. Despite the fall in house prices, the higher property-tax rate generates more tax revenue than before. This allows for an inital drop in the capital-income tax, especially in the first period where the government still has large revenes from land sales.[20] In the periods that follow, the capital-income tax is higher than its long-run level as the capital stock is lower than in the new steady state for an extended period of time. Over time, as both the stock of housing and business capital adjust in response to the reform, the capital-income tax that clears the government's budget falls.

[19]As the policy change is unexpected, we adjust households' cash-on-hand in the first period of the transition in three ways. First, the amount of bequests received falls as house prices drop. Second, cash-on-hand is adjusted for the new property tax rate and the capital-income tax rate. Third, the profits of the rental business and the construction firm become negative due to the unexpected increase in the property tax. The profit loss is taken lump-sum from households.

[20]The government's revenues from land sales in period $t + 1$ is determined by prices in period t. See Section 2.4 for details.



(a) Property tax τ_t^h

(b) Capital-income tax τ_t^k

(c) House price p_t^h

(d) Rental price p_t^r

(e) Wage rate w_t

(f) Interest rate r_t

FIGURE 5. Dynamics of key variables following a doubling of the property tax rate

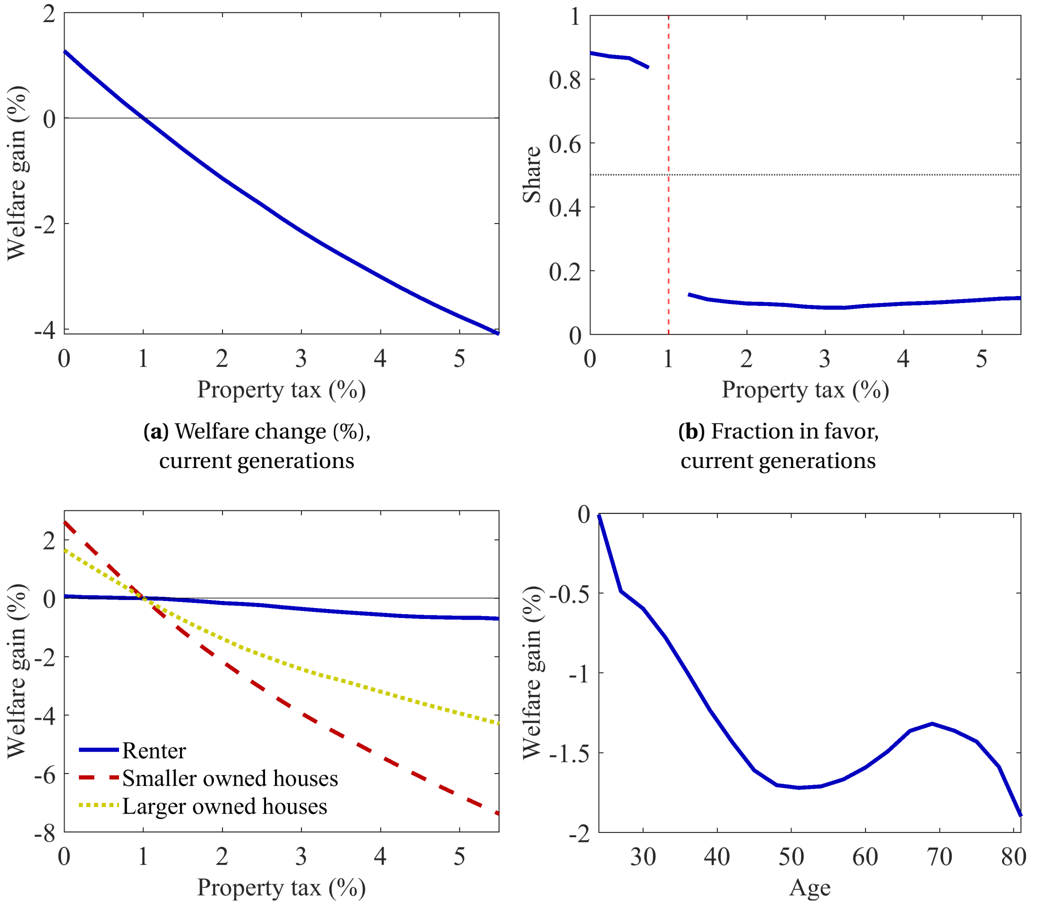
The fact that the capital stock is predetermined also has consequences for the equilibrium wage and interest rate, which are shown in Figure 5e and 5f. In the first period of the transition, the fixed amount of business capital implies that the marginal product of labor and capital are completely determined by the supply of labor. Since the tax reform suppresses house prices, homeowners experience a negative wealth shock, which they respond to by increasing the amount they work. Consequently, in the very short run, wages fall and the interest rate increases. Over time, we see a reallocation from housing capital towards business capital, which implies a gradual decrease in the interest rate and a growth in wages.

Let us now turn to welfare effects along the transition. Figure 6a presents welfare effects for the current population, across different levels of the property tax rate. The average welfare gain is decreasing in the property tax, meaning that current households prefer a reform that eliminates the property tax. This stands in stark contrast to the long-run results in Section 4. We also find that a majority of current households benefit from a lower property tax, as shown in Figure 6b, which illustrates the share of households who experience a welfare gain, as a function of the property tax rate.

There are several reason why current households prefer a lower property tax. Most importantly, a majority of households own their home. Homeowners incur welfare losses from higher property taxes not only because their property-tax payments increase but also since the drop in house prices reduces their housing equity. This negative wealth effect is most prominent for households who own relatively small houses, as shown in Figure 6c. The figure displays the average welfare effect across three groups of households, based on whether they are homeowners and the size of the house they own.

In the absence of financial frictions, all households in the model prefer owning a house as compared to renting, due to the intermediation cost of renting. However, due to the down-payment requirement and the minimum house size, households need to have sufficient savings for there to be optimal to become a homeowner. The group of households who buy small houses often use most of their financial wealth to purchase the house, and hence have limited savings in deposits. In contrast, those who own large houses are often wealthier and many of them have significant financial wealth in the form of deposits. While both groups of homeowners dislike the lower house prices and higher property taxes, the latter group benefits from the lower capital-income tax.

For renters, the welfare effects of altering the property and capital-income tax are relatively small on average. There are several channels through which a tax reform affects these households, and on average they largely cancel out. As seen in Figure 5d, rental rates fall in response to a higher property tax, which clearly benefits renters. On the other hand, renters suffer from the general-equilibrium effects on wages and interest rates. Since many renters are young and relatively poor, the immediate fall in wages has significant negative welfare consequences. Moreover, the initial increase in interest rates also makes borrowing more expensive for those who were planning on buying a house. In general, the relatively slow convergence towards lower interest rates and higher wages in the new steady state hurts the current generation of renters. For them, it had rather been preferred with the reverse path for both interest rates and wages, since many of



(a) Welfare change (%), current generations

(b) Fraction in favor, current generations

(c) Average welfare change (%), by housing situation

(d) Average welfare change (%), across age groups

FIGURE 6. Welfare consequences for current generations

Note: Figure 6a - 6c show effects across different levels of the property tax rate. “Smaller owned houses” are households that own $\underline{h}$, whereas “Larger owned houses” are households that own houses of a size larger than $\underline{h}$. A household is in favor of a policy if its welfare effect is greater than or equal to zero. Figure 6d displays the average welfare effect for each age group of the current generation, following a doubling of the property tax rate.

them are young and for life-cycle reasons expect higher earnings and savings in the future.

The distinction between renters and owners also explains much of the dispersion in welfare effects across cohorts, as seen in Figure 6d. Since the homeownership rate increases with age, older households are relatively worse off from a higher property tax and a lower capital-income tax. The age-group most negatively affected by the reform are those around the age of 50. Beyond that age, the homeownership rate is roughly constant and households instead differ in terms of their financial wealth. With household wealth peaking at the time of retirement, these households experience the largest benefit from the drop in the capital-income tax.

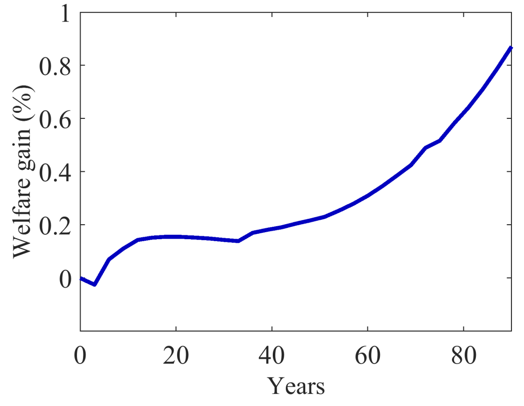


FIGURE 7. Welfare change (%) for newborn generations

Note: The welfare effect at each point in time is the average welfare effect of the newborn generation that enters the economy in that specific period, following a doubling of the property tax rate. The policy is implemented unexpectedly in period one (year 3).

Turning to the cohorts born along the transition path, Figure 7 illustrates the welfare gains for each newborn cohort for the case when the property tax is increased to 2 percent. The welfare gains are positive for all cohorts born along the transition, except for those who enter the economy in the period when the tax change takes place. Again, this drop in welfare is explained by the decrease in wages and the increase in interest rates in the first period, which hurt young households in particular. Later cohorts benefit from a higher property tax and a lower capital-income tax, for the same reasons as in the long-run analysis. As the economy slowly converges to the new steady state, so do the welfare gains among the newborn households.

Taken together, current generations benefit from a lower property tax whereas future generations prefer a much higher tax. The level of the optimal property tax that a social planner would choose therefore depends on the social discount factor Θ, which controls the weight assigned to future relative to current generations. With $\Theta = 0$ the planner only cares about current generations and would optimally choose $\tau_t^h = 0$. Also if the social discount factor is set equal to the households', i.e., $\Theta = \beta$, the weight on current households' welfare is sufficiently high to warrant a property tax of zero. If $\Theta = 1$, on the other hand, the planner cares equally about all generations and the optimal policy would be to set the property tax to the long-run optimal level. Figure 8 shows the optimal property tax, when accounting for the transitional dynamics, across different levels of the social discount factor. It is optimal to completely remove the property tax for a social discount factor below 0.984. Above that, the optimal tax is positive and grows quite quickly with the social discount factor.

In the transitions that we have analyzed so far, we considered immediate and permanent changes to the property tax. However, one could also imagine a policy where the property-tax is varying over time. With such a policy the planner could attempt to alleviate the negative welfare consequences for current generations, by allowing the property tax to increase over time or to pre-announce an increase. As such, it also opens up the

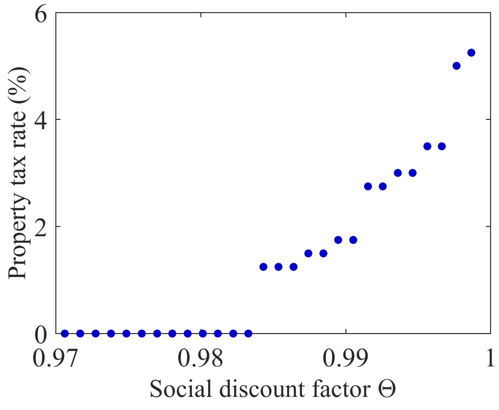


FIGURE 8. Optimal property tax, across the social discount factor

Note: Each marker represents the optimal property tax for a given level of the social discount factor. The tax is chosen from a grid with increments of 0.25 percentage points. Both the tax and the social discount factor are in annual values.

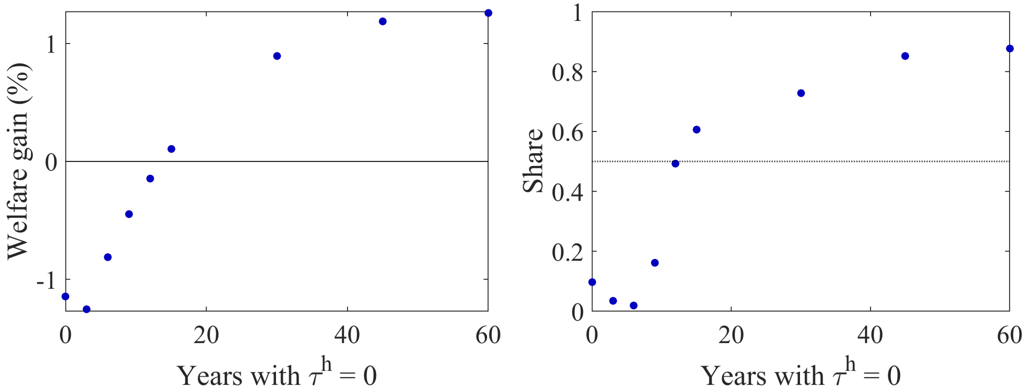
discussion about political feasibility. Is there a way in which a higher property tax, which is optimal in the long run, can receive support from a majority of current households? In the next section, we explore if such a policy is possible.

5.3 *Time-varying policies*

The once-and-for-all policies suggest that even if a planner wants to increase property taxes, it may be politically difficult to do so. A fundamental issue is that future generations benefit from higher property taxes, whereas current generations on average are better off with a lower property tax. This raises the question of whether there exists any policy that can make current households better off and allows for higher property taxes in the long run. Here, we present one potentially fruitful alternative. Specifically, we consider a time-varying policy which first removes the property tax completely to compensate current homeowners before the tax rate increases to 2 percent, to the benefit of future generations.[21]

We find that time-varying policies can improve welfare of a majority of current households. Figure 9a shows the average welfare change among current generations, where we vary the number of years the property tax is set to zero before it increases to 2 percent. The figure shows that current generations can benefit from such a policy. Average welfare is positive if the property tax is kept at zero for at least 15 years. More than 60 percent of current households are in favor of this policy, as shown in Figure 9b. Clearly, also newborn generations in the long run benefit from all of these time-varying policies, as the property tax eventually increases to the higher long-run value.

[21] In this analysis, we make a small, but important, change to the LTV constraint. Specifically, we assume that the LTV requirement is based on the house price in the next period whenever the agents know that the house price will fall. Without this assumption, households may end up with very high LTVs in the period that the property tax increases to its long-run level.



(a) Welfare change (%), current generations **(b)** Fraction in favor, current generations

FIGURE 9. Welfare effects of time-varying policies

Note: The welfare effect corresponds to the average welfare effect of the households alive at the time of the reform. The fraction of households in favor of a policy refers to the share of current households who experience a welfare gain from the policy.

For welfare to improve for current generations, it is crucial that the property tax is low for a sufficiently long time. A lower property tax also involves costs: to ensure tax neutrality, the capital-income tax increases, leading to less investments in business capital, which increase interest rates and reduce wages. Hence, these types of time-varying policies impact many newborn generations along the transition negatively. Moreover, if the property tax increases too quickly, house prices may fall already in the short run or do not increase enough to compensate homeowners for the higher future property tax. Since many households that are born throughout the transition phase are hurt by these policies, the implementation depends on a strong commitment by the government. Relatedly, if we would consider intergenerational altruism in the bequest motive, these policies would likely receive less support, since current households would then be directly linked to households who are negatively affected.

6. CONCLUSION

Motivated by the increasing importance of housing capital, we study optimal property taxation. To analyze who wins and who loses from changes in the property tax, we use a quantitative dynamic incomplete-markets model with households that differ with respect to labor income, asset holdings, and age. We consider revenue-neutral policies, where either the tax on capital income, labor income, or consumption adjusts in response to changes in the property tax, to clear the government's budget. In the model, aggregate effects on the demand for housing and deposit savings lead to endogenous changes in interest rates, wages, and house and rental prices.

We find that a planner who maximizes long-run aggregate efficiency or utilitarian welfare optimally sets the property tax rate at a substantially higher level than today. A higher property tax reduces house prices and causes a reallocation from housing capital to business capital, which in turn lowers interest rates and increases wages. These equilibrium effects have important consequences for welfare as they enable an improved consumption smoothing over the life cycle. A higher tax on housing is also beneficial as both the demand and supply of housing capital are relatively inelastic as compared to business capital. A property tax therefore has limited distortionary effects.

As today's generations have already made long-term investments with the current tax code in mind, it is important to acknowledge that the optimal policy in the long run is not necessarily beneficial for current households. In fact, we find that the preferred tax policy differs substantially across households. Newborn generations along the implementation phase benefit from the increase in wages and decline in interest rates and house prices, as the tax burden shifts towards housing. However, current homeowners suffer welfare losses due to falling house prices. As most current households own their home, the long-run optimal property tax proves difficult to implement and is not necessarily desirable. Time-varying policies can make a majority of current households in favor of a future increase in the property tax rate, but such policies hurt many future generations.

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