On the distributional effects of taxing housing

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Abstract

This paper illustrates the effects of certain commonly proposed housing tax reforms using an applied general equilibrium model with overlapping generations. In contrast to the previous literature, we focus on the short run effects by solving for the transitionary dynamics following the tax reforms. This allows us to analyze how the reforms influence the welfare of households living at the time of their implementation. We find that introducing a full capital income tax on the imputed rent of owner housing has very uneven welfare effects, with many households suffering substantial welfare losses. Elimininating the mortgage interest deductibility has somewhat more even distributional effects. However, it also makes fewer households better off than taxing the imputed rent.

Keywords: Housing taxation, welfare analysis, transitional dynamics

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1 Introduction

The US tax system favors owner housing. Unlike the return to other types of capital, the return to housing capital - the imputed rent - is untaxed. The tax code also allows deducting interest payments on mortgage loans from taxable income.[1] The preferential tax treatment of owner housing distorts households' consumption and savings behavior. The potential efficiency and welfare gains from eliminating the tax favored status of owner housing have been quantified, among others, by Gahvari (1985), Rosen (1985), Berkovec and Fullerton (1992), Poterba (1992), Skinner (1996), and Gervais (2002). Especially studies that employ dynamic general equilibrium models have found these gains to be substantial.

Despite the evidence on the distortions caused by the current tax system, policy proposals aiming to reduce the tax benefits of owner housing appear to face strong political opposition. The existing literature on housing taxation does not seem very helpful in understanding this 'status quo bias'.[2] In this regard, probably the most important shortcoming of the previous literature is that it is limited to a steady state analysis.[3] In this paper, we solve for the transitionary dynamics following certain housing tax reforms within an applied general equilibrium model with overlapping generations. This allows us to describe the distributional effects of the tax reforms among households that are alive when the reforms are implemented. In our view, this is crucial in order to understand the political discussion around housing's tax status.

We build on Gervais (2002) which analyzes the steady state effects of housing tax reforms using a general equilibrium overlapping generations model. In his model, the aggregate capital stock is disaggregated into housing and business capital and the tax system distinguishes between the imputed rent from owner housing, the interest income from a financial asset, and mortgage

[1] Most OECD countries either do not tax the imputed rent at all or tax it only at very low effective rates. Most of them also allow a mortgage interest deduction. See Hendershott and White (2000) for a recent international comparison of housing taxation.

[2] As far as we know, only Berkovec and Fullerton (1992) show explicitly that taxing housing would hurt some households. Unlike our model, their model is static.

[3] Skinner (1996) is an expection. However, he doesn't consider distributional issues.

interest payments.

Our model differs in three main ways from the model in Gervais (2002). First, we introduce idiosyncratic labor income shocks. This creates a large degree of wealth heterogeneity and allows us to study how the welfare effects of the tax reforms depend on households' net worth position. Second, we assume that housing capital is irreversible. In the absence of such a constraint, existing housing capital could be costlessly converted into consumption goods or business capital which seems unrealistic. The irreversibility constraint influences the dynamics of the wage and interest rate by slowing down the convergence of the business capital stock towards its new steady state level following a tax reform. It also implies that the tax reforms may change the relative price of housing capital. House price effects are indeed a concern with tax reforms that reduce the demand for housing. This is because even a relatively moderate decline in house prices creates large capital losses for highly leveraged home owners.[4] In our model, a tax reform may affect households' net worth by changing unexpectedly the market value of their housing capital. Third, we consider only owner housing whereas the model in Gervais (2002) features a tenure choice based on the interaction of a down payment constraint, a minimum house size, and tax incentives. Abstracting from the tenure choice simplifies the analysis substantially.[5] It also seems clear that at least

[4] Following this concern, some research has attempted to estimate how different tax reforms would affect housing prices in the short run. For instance, Bruce and Holtz-Eakin (1999) consider the effects of a flat tax reform on house prices. Poterba (1984) briefly considers the house price effects of tax reforms similar to those analyzed here. These studies, however, cannot account for welfare effects.

[5] One reason why introducing a rental market in our set-up is problematic is related to the house price effects. In our model, the amount of owner housing a household has is always uniquely determined by the consumption demand for housing. In contrast, in the presence of a rental market households would be indifferent between investing in financial assets or rental housing. This is because there is no aggregate uncertainty in the model. Therefore, households must expect to receive the same after-tax return for financial assets and rental housing. However, following the announcement of a tax reform, the relative price of existing housing capital changes. Hence, ex post the net worth of the households does depend on how they allocated their wealth between financial assets and rental housing. Properly modelling the investment decision between financial assets and rental housing would require a very different modelling approach.

most of the renters are likely to benefit from the tax reforms considered because they reduce the benefits of owner housing. Given that our focus is on the short run distributional effects, home owners are therefore a more interesting group than renters.

We first consider tax reforms that involve taxing the imputed rent at the same rate as other capital income. We find, in line with the results in Gervais (2002), that the reforms increase the business capital stock substantially and create relatively large steady state welfare gains for households with very different lifetime earnings expectations. However, the short run welfare effects of the tax reforms are very uneven. A large fraction of households living at the time of the reform are worse off compared to the status quo. Old households tend to lose the most. One reason for this is that due to life cycle savings motives, old households have a very large fraction of their total wealth in the form of housing. Therefore, taxing housing increases their overall tax bill. Along the net worth dimension, the distributional effect depends on whether we lower, as a result of the broader tax base, the tax rates on both labor income and financial interest income or on interest income alone. In general, the distributional effects are largely driven by general equilibrium interest and wage rage effects. Taxing the imputed rent also implies a temporary fall in the house price. it turns out that the house price fall has a major welfare effect only on the old households.

We also experiment with eliminating mortgage interest deductibility without imposing a tax on the imputed rent. Again, this reform implies substantial steady state welfare gains for all households. In the short run, it has somewhat more moderate distributional effects than taxing the imputed rent. However, it also makes very few households better off.

In the next section we present the model and the tax reforms considered. In section 3 we present the results. We conclude in section 4. We discuss some computational issues in the appendix.

2 The model

We consider a general equilibrium overlapping generations economy where households face idiosyncratic uncertainty about their labor productivity. The absence of contracts contingent on labor productivity shocks gives rise to an intragenerational wealth distribution.[6] Housing and housing taxation are introduced following Gervais (2002). We also introduce a pay-as-you-go social security system.

2.1 Demographics and endowments

The economy is populated by a continuum of households that live for a maximum of J periods. Households face a positive probability of death in every period. The probability of surviving from age j to $j+1$ is denoted by ψ_j. In each period, a continuum of new households is born so that the mass of the population is constant over time.

Households enter their lives with no assets. They have a labor endowment of one unit which they supply inelastically. The average labor productivity of households of age j is given by e_j. Retirement occurs at age $j = j_r$. Formally, we have $e_j > 0$ for $j < j_r$ and $e_j = 0$ for $j \geq j_r$. Households also face idiosyncratic labor productivity shocks denoted by $\xi > 0$, with $\xi \in \mathbf{E} = \{\xi_1, \xi_{2,}, ...\xi_n\}$. These shocks follow a finite-state, first-order Markov process with stationary transition probabilities given by

$$Q(\xi', \xi) = prob(\xi_{t+1} = \xi' | \xi_t = \xi).$$

This process will be chosen so that the probability distribution over $\mathbf{E}$ converges to a unique time-invariant distribution. It is assumed that the distribution of the initial labor income shocks of new born households corresponds to the limit distribution.

[6] There are several papers which employ a similar overlapping generations model with idiosyncratic uncertainty. One of the first ones is İmrohoroğlu et al. (1995). Conesa and Krueger (1999) use a similar model solving also for the transitionary dynamics. Both of these papers focus on social security.

2.2 Technology

Aggregate production function is of the Cobb-Douglas form

$$f(K_t, N) = K_t^{\alpha} N^{1-\alpha}, \tag{1}$$

where $\alpha \in (0, 1)$ is the capital share, K_t is the aggregate business capital stock, and $N > 0$ is the aggregate effective labor which is constant over time. The interest rate and the wage rate are

$$r_t = \alpha K_t^{\alpha-1} N^{1-\alpha} - \delta_k \tag{2}$$

and

$$w_t = (1 - \alpha) K_t^{\alpha} N^{-\alpha}, \tag{3}$$

respectively.

Housing capital is produced by a competitive construction firm. In period t, the firm buys 'old' housing capital H_t from the households, invests I_t^h, and sells 'new' housing capital, H_{t+1} to the households. It chooses H_t and I_t^h so as to maximize:

$$\{p_t^n H_{t+1} - p_t^o H_t - I_t^h\} \tag{4}$$

subject to

$$H_{t+1} = (1 - \delta_h) H_t + I_t^h \tag{5}$$

$$I_t^h \geq 0. \tag{6}$$

Here p_t^n denotes the price of new housing capital and p_t^o the price of old housing capital in period t. Parameter $0 < \delta_h \leq 1$ denotes the depreciation rate of housing capital. The first constraint states that the amount of 'new' housing equals the stock of 'old' housing, net of depreciation, plus new housing investment. The second constraint is the irreversibility constraint. Introducing an irreversibility constraint is the simplest way to rule out the possibility of converting existing housing capital into business capital or consumption goods.[7] It is also because of this constraint

[7] A similar irreversibility constraint on business capital would not be binding following any of the tax reforms we consider. This is because all tax reforms lead to a higher business capital stock.

that the price of one unit of housing capital may differ from the price of the investment goods or the consumption good, which are normalized to one.

Assuming that the construction firm makes zero profits every period, its problem implies that

$$p_t^n \leq 1 \tag{7}$$

$$p_t^0 = (1-\delta_h)p_t^n \tag{8}$$

$$\text{if } p_t^n < 1, \text{ then } I_t^h = 0 \tag{9}$$

Given that $\delta_h > 0$, the steady price of new housing capital must be equal to one.

2.3 Government

The government finances a constant amount of public consumption, G, every period and administers a social security program on a pay-as-you-go basis. It is required to maintain a balanced budget in all periods. Tax rates on labor income and financial interest income are denoted by $\tau^l \geq 0$ and $\tau^a \geq 0$, respectively. We will refer to them as labor and capital tax rates. The imputed rent, net of depreciation and maintenance cost, from owner housing of size h is defined as rh. The tax on the imputed rent, or housing tax, is denoted by $\tau^h \geq 0$. Furthermore, households can deduct a fraction $0 \leq \tau^m \leq 1$ of the mortgage interest payments from taxable income. We assume that the deduction rate is determined by the tax rate on the financial interest income. The government budget constraint is shown below in section 2.5.

The tax system in our model is as in Gervais (2002), with the exception that we allow for different labor and capital taxes (τ^l and τ^a). This allows us to experiment with different ways of adjusting other tax rates when imposing a tax on the imputed rent. In order to enhance the comparability of our results to those in Gervais (2002), we set $\tau^l = \tau^a$ in the initial steady state.

The social security program gives households a social security benefit which is denoted by $b_{j,t}$. For households below the retirement age, the benefit is zero. For retired households it is determined as a fraction $\theta \in [0, 1]$ of the average wage income. The social security benefits and the pay-as-you-go equilibrium conditions are formally defined below in section 2.5.

Social security benefits are subject to the labor income tax. Therefore, lowering the labor income tax will benefit, *ceteris paribus*, also the retired households. This is important for the distributional effects of the tax reforms. In the absence of a social security system, retired households would rely solely on capital income.

2.4 Household's problem

Households derive utility from consumption, c, and housing, h. One unit of housing entails a direct maintenance cost of κ. In addition to housing, households can accumulate wealth with financial assets denoted by $a \geq 0$. Households can also borrow by taking a mortgage loan, which is denoted by $m \geq 0$.

Households have no altruistic bequest motives. However, we assume that they cannot insure themselves against lifetime uncertainty, i.e. there are no annuities. Therefore, households leave accidental bequests. These are distributed uniformly as lump-sum transfers, Tr, to households currently alive.

At the beginning of the period, households first observe their current labor productivity shock. Households then supply labor (inelastically), production takes place, and households receive wage and interest income as well as the transfer from accidental bequests and the social security benefit. Finally, households make their consumption-savings decisions: This involves buying new housing capital which is assumed to give utility in the same period.

The individual state variables are net worth, y, current labor income shock, ξ, and age, j. Net worth consists of housing, financial assets and mortgages net of taxes and maintenance costs. The household problem is written recursively as follows, with c_t, h'_t, m'_t, a'_t as the associated policy functions:

$$V_t(y_t, \xi, j) = \max_{c_t, h'_t, m'_t, a'_t} \left\{ \frac{(c^\rho h'^{1-\rho})^{1-\sigma}}{1-\sigma} + \beta \psi_j E_{\xi'|\xi} V_{t+1}(y_{t+1}, \xi', j+1) \right\} \tag{10}$$

subject to

$$c_t + p_t^n h_t' + a_t' - m_t' \leq y_t + (1 - \tau_t^l - \tau_t^s)\xi e_j w_t + (1 - \tau_t^l) b_{j,t} + Tr_t \tag{11}$$

$$\begin{aligned} y_{t+1} &= (p_{t+1}^o - \kappa - \tau_{t+1}^h r_{t+1}) h_t' + [1 + (1 - \tau_{t+1}^a) r_{t+1}] a_t' \\ &\quad -[1 + (1 - \tau^m \tau_{t+1}^a) r_{t+1}] m_t' \end{aligned} \tag{12}$$

$$a_t' \geq 0, \; m_t' \geq 0, \; a_t' m_t' = 0 \tag{13}$$

$$y_{t+1} \geq 0 \tag{14}$$

The parameter σ measures the risk aversion, ρ is the consumption share of the consumption good, and β is the discount factor. Constraints (11) and (12) form the flow budget constraint. On the left hand side of (11) we have consumption, the value of new housing, the financial asset, and the mortgage. On the right hand side, we have current net worth, net labor income and pension benefits, and the transfer that the household receives from accidental bequests. Net worth in the following period is defined by constraint (12). It consists of the value of housing net of maintenance cost and the tax on the imputed rent plus the after-tax value of current financial savings and the mortgage. The inequalities in (13) define the financial asset and the mortgage to be non-negative. We also require that either financial assets or the mortgage is zero. This is to determine the optimal portfolio also in the case where the after-tax return is the same in absolute value for these two assets, which happens when $\tau^m = 1$. The last constraint imposes a non-negativity constraint on net worth. We do not impose a separate down payment constraint (as in Gervais 2002) because this non-negativity constraint on net worth already implies a maximum mortgage-to-housing ratio.

2.5 The user cost of housing

In order to clarify the household's portfolio problem and housing's tax status, it is useful to consider the problem of a household with current wealth y who wishes to transfer wealth y' to the following period. Using the steady state prices of housing capital and the household budget constraints (11 and 12) one can write consumption as a function of housing demand as follows:[8]

$$c = Y - \frac{y' + (r + \delta_h + \kappa)h' + (\tau^h - \tau^a)rh' + (1 - \tau^m)\tau^a rm'}{1 + (1 - \tau^a)r} \tag{15}$$

where $Y = y + (1 - \tau^l - \tau^s)\xi e_j w + (1 - \tau^l)b_j + Tr$. This equation shows the user cost of housing in terms of current consumption. The user cost depends on the tax incentives through τ^h, τ^a, and τ^m. When mortgage interest payments are fully tax deductible ($\tau^m = 1$), the size of the mortgage doesn't affect the user cost. This means that the household is indifferent between financing its housing with own savings or with a mortgage. When $\tau^m < 1$, the user cost of housing increases with the size of the mortgage.

2.6 The tax reforms

At the time of a reform, the economy is assumed to be in a steady state. At the beginning of period $t = 1$, before household decisions are made, the government announces a sequence of new tax rates for periods $1, 2, ...$ As is usual with this kind of policy experiments, it is assumed that the tax reform is a zero-probability event and that the households are not insured against it.

The initial tax system is characterized by $\tau_0^h = 0$, $\tau_0^m = 1$, and $\tau_0^a = \tau_0^l > 0$. In words, consistently with the current US tax system, the imputed rent is not taxed and mortgage interest payments are fully tax deductible.[9] For simplicity, we set the initial tax rates on labor and capital income to be equal.

We consider the following four tax reforms:

Reform 1: The government imposes a tax on the imputed rent starting from period 1 and uses the additional tax revenue to lower both labor and capital taxes. Thus, $\tau_t^h = \tau_t^a = \tau_t^l$ and

[8] To get this, one needs to assume that both a' and m' can be strictly positive and then solve for a' from (12) and subsitute it into 11.

[9] Property taxes are often considered as a non-distortionary fee for government services rather than a tax. Fullerton (1987) estimates the average effective tax rates on housing and non-housing capital to be -5% and 25%, respectively, when property taxes are not included. With property taxes, the estimates become 19% for housing capital and 36% for non-housing capital.

$\tau_t^m = 1$ for $t \geq 1$.

Reform 2: The government imposes a tax on the imputed rent starting from period 1 but keeps labor tax fixed. Thus, $\tau_t^h = \tau_t^a$, $\tau_t^l = \tau_0^l$, $\tau_t^m = 1$, for $t \geq 1$.

Reform 3: The government announces in period 1 the taxation of the imputed rent starting from period 10. The additional tax revenue is used to lower both labor and capital taxes. Thus, $\tau_t^h = 0$, $\tau_t^a = \tau_t^l$, $\tau_t^m = 1$ for $1 \leq t < 10$ and $\tau_t^h = \tau_t^a = \tau_t^l$, $\tau_t^m = 1$, for $t \geq 10$.

Reform 4: The government removes mortgage interest deductibility starting from period 1 lowering both labor and capital income taxes. Thus, $\tau_t^h = 0$, $\tau_t^a = \tau_t^l$ and $\tau_t^m = 0$ for $t \geq 1$.

2.7 Welfare measures

Throughout the paper, we measure welfare effects as the equivalent consumption good variation. This measure gives the constant percentage increment in future consumption of the consumption good (keeping housing fixed) that would give a household the same expected remaining lifetime utility in the status quo than what it obtains with the reform.

Given the form of the utility function, the equivalent consumption good variation can be computed directly from the value functions. However, the evaluation of welfare effects is complicated by the fact that, in general, tax reforms change the net worth of households. Consider a household in period 1 when the reform takes place. Its age is s and its labor income shock is e. Let its net worth be y^I with initial steady state prices and tax rates. The tax reform may change the current price of old housing capital, p_1^o, as well as the period 1 tax rates. Therefore, let the net worth be y^N with the equilibrium house price and tax rates given that a tax reform takes place. Also let V^I denote the value function in the initial steady state and V_1^N the value function in period 1 with a tax reform. The welfare gain of the household, say ecv, is given by

$$ecv = \left(\frac{V^N(y^N, e, 1)}{V^I(y^I, e, 1)} \right)^{\frac{1}{\rho(1-\sigma)}} - 1.$$

A positive value means that the household is better off with the tax reform compared to the status quo, while a negative value means that it is worse off.

2.8 Competitive equilibrium

The household state variables are net worth $y \in \mathbf{Y} \subset \mathbf{R}$, current labor income shock ξ, and age $j \in \mathbf{J} = \{1, 2, ..., J\}$. Therefore, let $B(\mathbf{Y})$ denote the borel sets that are subsets of $\mathbf{Y}$ and let $P(\mathbf{E})$ and $P(\mathbf{J})$ denote the power sets of $\mathbf{E}$ and $\mathbf{J}$. respectively. The distribution of households over their individual states in period t is given by Φ_t, which belongs to the set of all finite measure over the space $(\mathbf{Y} \times \mathbf{E} \times \mathbf{J}, B(\mathbf{Y}) \times P(\mathbf{E}) \times P(\mathbf{J}))$.

Households' net worth in period 1 is in general different from what they expected and the difference depends on their portfolio. This is because of the unexpected changes in house prices and tax rates. Therefore, the distribution of households over their individual states is not enough for a full characterization of the initial aggregate state in period 1. Instead, we need to include a probability measure over individual *portfolios,* as determined from their policies $\{a_0', m_0', h_0'\} \in \mathbf{R}_+^3$.

Therefore, let $\mathbf{B}(\mathbf{R}_+^3)$ denote the Borel sets that are subsets of $\mathbf{R}_+^3$. The initial distribution of households in period 1 is given by Ψ_1, which is defined as the probability measure over all possible portfolios as determined from their period 0 policies, $\{a_0', m_0', h_0'\}$, labor income status, and age. Thus, Ψ_1 is defined over the space $(\mathbf{R}_+^3 \times \mathbf{E} \times \mathbf{J}, B(\mathbf{R}_+^3) \times P(\mathbf{E}) \times P(\mathbf{J}))$.

We can now define the competive equilibrium as follows.

Given a sequence of tax rates $\{\tau_t^l, \tau_t^a, \tau^h, \tau_t^m, \tau^s\}_{t=1}^{\infty}$ and initial conditions $\{K_1,\ H_1,\ \Psi_1\}$, the equilibrium is a sequence of individual functions $\{V_t,\ h_t',\ a_t',\ m_t',\ c_t : \mathbf{W} \to \mathbf{R}_+\}_{t=1}^{\infty}$, aggregates $\{K_t, H_t, D_t, M_t\}_{t=1}^{\infty}$, prices $\{w_t,\ r_t,\ p_t^n,\ p_t^o\}_{t=1}^{\infty}$, transfers $\{Tr_t\}_{t=1}^{\infty}$, social security benefits $\{b_t\}_{t=1}^{\infty}$ and a sequence of measures $\{\Phi_t\}_{t=1}^{\infty}$, such that:

1) Given household policies in period $t \geq 0$, $\{a_t', m_t', h_t'\}$, household net worth in period $t+1$ is defined as

$$
\begin{aligned}
(16) \qquad y_{t+1} \;=\; & (p_t^o - \kappa - \tau_{t+1}^h r_{t+1}) h_t' + [1 + (1 - \tau_{t+1}^a) r_{t+1}] a_{t+1}' \\
& - [1 + (1 - \tau_{t+1}^m \tau_{t+1}^a) r_{t+1}^m] m_{t+1}'
\end{aligned}
$$

2) Given prices and tax rates, individual functions solve (10)-(14).

3) Factor prices r_t and w_t satisfy (2) and (3).

4) House prices and housing investment satisfy (5)-(9).

5) Markets clear:

$$H_{t+1} = \int h_t' \Phi_t(dy \times d\xi \times dj) \tag{17}$$

$$A_{t+1} = \int a_t' \Phi_t(dy \times d\xi \times dj) \tag{18}$$

$$M_{t+1} = \int m_t' \Phi_t(dy \times d\xi \times dj) \tag{19}$$

$$C_t = \int c_t \Phi_t(dy \times d\xi \times dj) \tag{20}$$

$$K_{t+1} = A_{t+1} - M_{t+1} \tag{21}$$

$$C_t + G + K_{t+1} + H_{t+1} = (1 - \delta_k)K_t + (1 - \delta_h - \kappa)H_t + K_t^{\alpha} N^{1-\alpha}. \tag{22}$$

6) Government policies satisfy

$$G = \tau_t^a r_t A_t + \tau_t^h r_t H_t - \tau_t^m \tau_t^a r_t M_t + \tau_t^l w_t N + \tau_t^l \int b_t \Phi_t(dy \times d\xi \times dj) \tag{23}$$

$$b_{j,t} = \{ \begin{array}{c} 0, \text{ for } j = 1, 2, ...j_r - 1 \\ \theta \frac{w_t N}{\int \Phi_t(dy \times d\varepsilon \times \{1, ..., j_r - 1\})}, \text{ for } j = j_r, j_r + 1, ..., J \end{array} \tag{24}$$

$$\tau^s w_t N = b_{j,t} \int \Phi_t(dy \times d\varepsilon \times \{j_r, ..., J\}) \tag{25}$$

7) Transfers are given by

$$Tr_{t+1} = \int (1 - \psi_j) y_{t+1} \Phi_t(dy \times d\xi \times dj) \tag{26}$$

8) The distribution of households over their individual states evolves as $\Phi_{t+1} = H(\Phi_t)$, where the function H follows from demographics and individual policy functions.

It is perhaps useful to check that the aggregate consistency condition (22) is implied by the household and the government budget constraints together with equilibrium prices. In this respect, the somewhat non-standard feature in our model is the problem of the construction firm. It is straightforward to aggregate first, without considering the problem of the construction firm, the individual budget constraints (11) and (12) so as to get

$$C_t + G + K_{t+1} + p_t^n H_{t+1} = K_t^\alpha N^{1-\alpha} + (1-\delta_k)K_t + (p_t^o - \kappa)H_t \tag{27}$$

Assume that $p_t^n = 1$. Then, by (8) we have $p_t^o = (1-\delta_h)$. Substituting these prices into the above equation gives us the aggregate consistency condition (22). Assume then that $p_t^n < 1$. Then by (8) and (9) we have $H_{t+1} = (1-\delta_h)H_t$ and $p_t^o = (1-\delta_h)p_t^n$. Substituting these prices and quantities into (27) again results in (22).

2.9 Calibration

The model period corresponds to one year. We think of households as being born at real life age 25, retiring at age 65, and dying with certainty at age 85. These assumptions imply $J = 60$ and $j_r = 40$. The survival probabilities have been computed from the year 2000 US Life Table for males as provided by the US Social Security Administration.[10]

We take the stochastic part of the labor productivity process from Conesa and Krueger (1999). The labor productivity shock, ξ, may take two values - $\xi_1 = 0.5$ and $\xi_2 = 3.0$ - with persistence probabilities of 0.9811 and 0.9261, respectively. The transition probabilities imply a stationary distribution where approximately 80% of the individuals have the lower labor productivity shock. They match the labor income mobility between the first four and the fifth labor income quintile in the Panel Study of Income Dynamics (PSID) as reported in Días-Giménez et al. (1997).

We estimate the age-profile of labor income, $\{e_j\}$, from the 1999 family wave of the PSID.[11] The least squares estimates are as follows

$$\log(labor\ income) = 7.7799 + 0.1311 age - 0.0015 age^2$$

[10] http://www.ssa.gov.

[11] We use the labor income of the household head. We consider only families who report to own their main residence and where the household head is between 25 to 62 years old and earns a strictly positive labor income.

This gives a usual hump-shaped pattern for labor income which peaks at real age 44. We further normalized the profile so that the aggregate effective labor is equal to one, i.e. $N = 1$.

The risk-aversion parameter σ is set at $\sigma = 2$. We follow Gervais (2002) in defining housing capital broadly so as to include durable goods and take take the technology parameters and aggregate targets from his paper.[12] The depreciation rate of business capital is set at $\delta_k = 0.0809$ and the capital share of output at $\alpha = 0.29$.[13] In the benchmark calibration, the depreciation rate of housing capital is set at $\delta_h = 0.01$ and the maintenance cost of housing at $\kappa = 0.0509$. The sum of these two parameters equals Gervais' estimate for the depreciation rate of housing capital, when housing is broadly defined to include durable goods. The depreciation rate of housing is a key parameter in the sense that it determines how fast the supply of housing can adjust downwards. We will therefore do some sensitivity analysis with it.

The social security system is fully determined by the contribution rate, which we set at $\tau^s = 0.125$. This corresponds to the actual current US social security payroll tax rate when contributions to Medicare are excluded. In the initial steady state $\tau^m = 1$, $\tau^h = 0$, and $\tau^l = \tau^a$. This implies the same tax structure as in Gervais (2002).

We choose the remaining preference parameters $\{\beta, \rho\}$ and the tax rate τ^l (and $\tau^a = \tau^l$) so that the model replicates the following three targets in the initial steady state. 1) Total housing capital stock-to-total capital stock ratio $H/(K + H) = 0.547$. 2) Total capital stock-to-total output ratio $(K + H)/Y = 3.0$, where $Y = K^\alpha N^{1-\alpha} + (r + \kappa + \delta_h)H$. 3) Public consumption-to-total output ratio $G/Y = 0.195$. The resulting parameter values are: $\beta = 0.959$, $\rho = 0.650$, and $\tau^l = 0.271$.

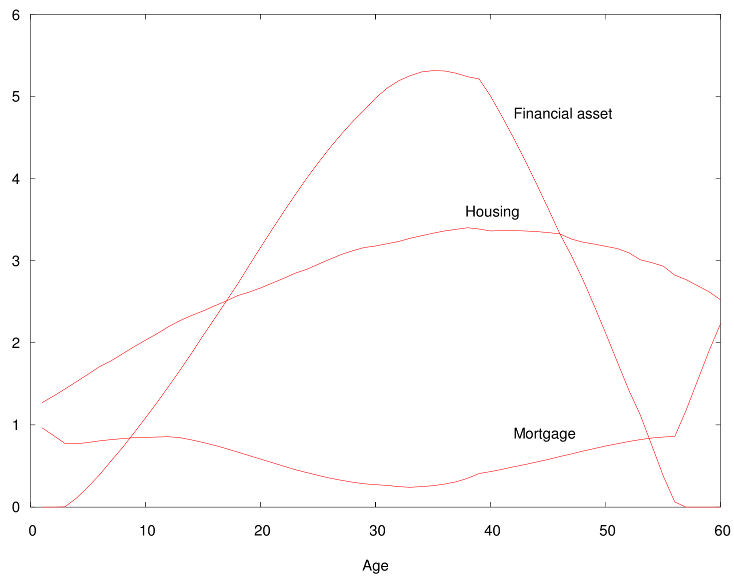
[12] Gervais uses the 1993 Fixed Reproducible Tangible Wealth published by U.S. Department of Commerce

[13] The estimate for the capital share is from Greenwood et al. (1995), who measur the share of business capital in the production function, when the total capital stock is disaggregated into housing and business capital.

2.10 Average portfolios over the life cycle and the distribution of net worth and housing wealth

We display average housing, mortgage and net worth over the life cycle in the initial steady state in figure 1. All households choose the have zero financial assets in the first periods of their lives. The same is true for very old households. The average mortgage loan is high during the first years, especially relative to the average housing. The average mortgage loan peaks up again at the very old age. Average housing increase steadily until about model age 40. This reflects both binding borrowing constraints and a precautionary savings motive.

FIGURE 1. AVERAGE PORTFOLIO PROFILE OVER THE LIFE CYCLE.



It is also interesting to look at the joint distribution of housing and net worth across all households in the initial steady state. This is done in table 1. For this table, we first sort the households by their net worth, and then present the share of net worth and housing wealth owned by households in different net worth quintiles. The data is the 2001 wave of the Survey of Consumer Finances.[14] In the data, housing wealth is much more evenly distributed across

[14] We considered only families where the household head is at least 25 years old and who own their main residence. Our empirical measure of housing wealth is here the sum of the value of the main residence and other residencial housing. In other words, it does not include durable goods.

different net worth quintiles than net worth. The model displays this same feature. In the model economy, the net worth distribution, as represented by the net worth quintiles, seems to be somewhat more uneven and the housing wealth distribution less uneven than in the data.[15]

TABLE 1. DISTRIBUTION OF HOUSING AND NET WORTH (%).

	Data		Model	
Net worth	Net worth	Housing	Net worth	Housing
0-20	0.9	6.0	0.0	8.8
20-40	3.1	9.4	1.2	9.9
40-60	6.3	14	3.5	10
60-80	13	21	7.8	13
80-100	77	49	89	55

3 Results

In this section we present our results about the effects of different housing tax reforms. We first present and discuss the steady state effects. We then explain how the aggregate transitional dynamics following the tax reforms look like. Finally, we proceed to describe the distributional effects of the tax reforms among households that are alive when they are implemented.

3.1 Steady state effects of the tax reforms

Table 2 presents the main steady state aggregate quantitities both in the initial steady state and the post reform steady states. Reform 3, which is like Reform 1 but postponed by 10 periods, has obviously the same steady state effects as Reform 1. Consider first Reforms 1 and 2. Taxing the imputed rent allows for lowering either all income tax rates from 0.271 to 0.231 (Reform 1) or only the capital income tax rate from 0.271 to 0.118 if labor income taxes are unchanged

[15] On the other hand, the share of net worth owned by the very top of the wealth distribution (say, 99-100) is far smaller in the model than in the data. See Díaz-Giménez et al. (1997) for an account of the US earnings and wealth inequality.

(Reform 2). The main aggregate variables are affected very similarly under both reforms. The business capital stock increases by 10% with Reform 1 and by 12% with Reform 2. Consequently, in the new steady states, the interest rate is lower and the wage rate is higher. The housing stock decreases by 4.3% with Reform 1 and by 3.4% with Reform 2.

Reform 4, which eliminates the mortgage interest deductibility, allows for lowering capital and labor taxes only by about one percentage point. Therefore, it has a more modest impact on the long run capital stocks than the other reforms which involve taxing the imputed rent. The stock of business capital increases 5.8%. It is remarkable, that the aggregate stock of housing actually increases slightly (by 2.6%). The main effect of this reform is a reduction in the household borrowing. The average mortgage decreases by 36%.

TABLE 2. STEADY STATE EFFECTS OF THE TAX REFORMS.

	Initial steady state	Reforms 1 and 3	Reform 2	Reform 4
τ^a	0.271	0.231	0.118	0.262
τ^l	0.271	0.231	0.271	0.262
τ^h	0.000	0.231	0.118	0.000
τ^m	1.000	1.000	1.000	0.000
H	2.734	2.617	2.642	2.742
K	2.263	2.503	2.541	2.402
M	0.577	0.591	0.533	0.372
r (%)	8.149	7.029	6.986	7.475
w	0.900	0.926	0.930	0.9155
ecv_{ε_1}	0.0%	8.1%	2.3%	0.6%
ecv_{ε_2}	0.0%	5.1%	2.3%	2.8%

We also show the steady state welfare effects in Table 2. Recall that the labor productivity shocks are quite persistent, thus a household that is born with a low labor productivity has very different earnings prospects than one with a high initial labor productivity. Reform 1 would generate a welfare gain of 8.1% to households with a low initial labor productivity - an overwhelming majority of 80% - and a somewhat smaller welfare gain of 5.1% to those with a high initial labor productivity. The welfare gains of Reform 2 are also substantial but much smaller than those of Reform 1. Young households prefer to have lower labor taxes rather than low capital taxes because that gives them more resources early in life which allows them to better smooth their life cycle consumption and housing profiles. Eliminating mortgage interest deductibility (Reform 4) benefits households with a good initial labor productivity far more than those with a bad initial shock.

3.2 Aggregate transitional dynamics

Figure 2 shows the transition paths of housing and business capital stocks following Reform 1. The irreversibility condition (6) is binding for the first 9 periods. The user-cost for housing has increased both because of the tax on the imputed rent and the increased after-tax return to the financial asset. Therefore, households would like to immediately reduce their housing wealth. The housing stock eventually reaches its new steady state level from below. That is, the short run effect of the tax reform on the housing stock is larger than the long run effect. The business capital stock, in contrast, increases monotonically towards its new steady state level.

FIGURE 2. CAPITAL STOCKS AFTER REFORM 1.

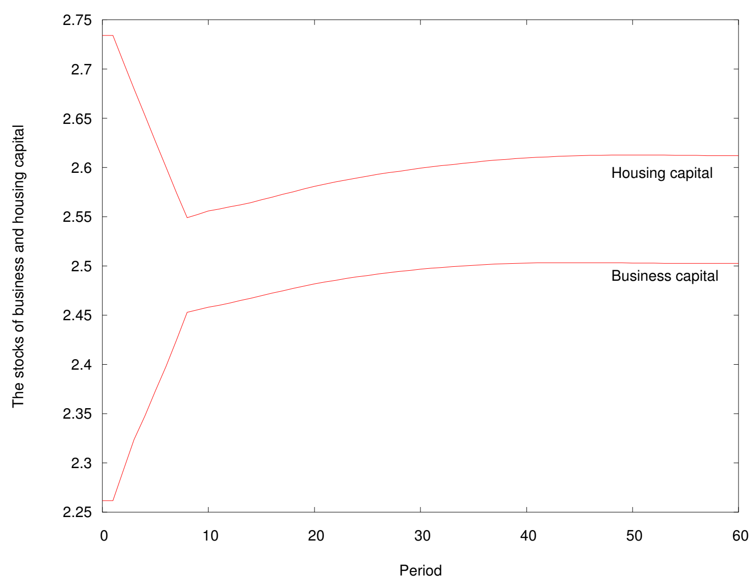
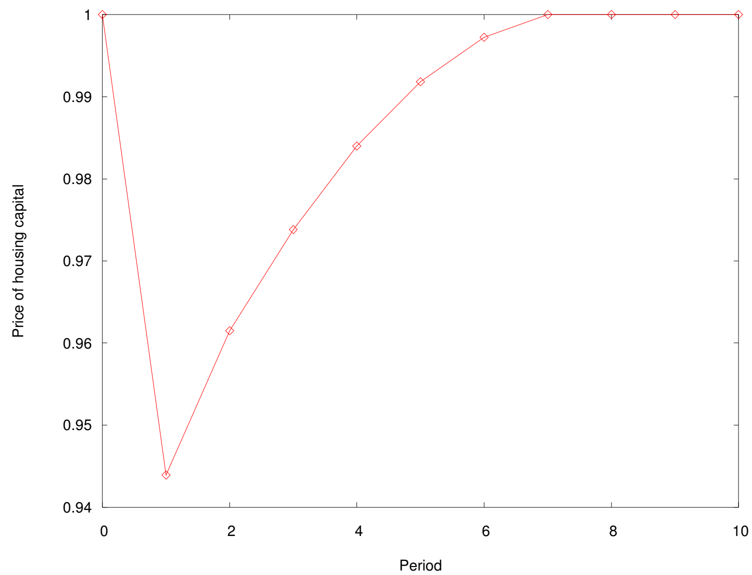


Figure 3 displays the price of new housing after Reform 1. The price of housing capital falls initially by 5.7% and then converges back to the steady state level in 7 periods. During this time, the increasing price level creates capital gains for those who invest in housing. This effect balances the supply of and demand for housing during the first periods after the reform.

FIGURE 3. THE PRICE OF NEW HOUSING CAPITAL AFTER REFORM 1.



The dynamics of the interest and wage rates (not shown) follow that of the business capital stock: the interest rate decreases and the wage rate increases during the transition towards the new steady state. The tax rates that balance the budget (not shown) turn out to display very little variation over time: they are close to their new steady state levels already in period 1.

The aggregate dynamics following Reform 2 (not shown) are quite similar to those following Reform 1. House prices fall by 5% in period 1. Following Reform 4, the demand for housing increases in the long run. However, in the short run the aggregate demand for housing (not shown) decreases enough to make the irreversibility constraint binding in period 1 and the price of housing falls by 0.5%.

In Reform 3, the taxation of the imputed rent is postponed by 10 periods from the announcement of the tax reform. Therefore, the reform implies quite different transitional dynamics than the other reforms. Figure 4 shows the evolution of the two capital stocks and figure 5 the dynamics of the price of new housing capital following Reform 3. Note that the price of housing capital starts to fall already in period 6, before the implementation of the tax reform. Falling house prices reduce the demand for housing before the imputed rent is taxed.

FIGURE 4. CAPITAL STOCKS AFTER REFORM 3.

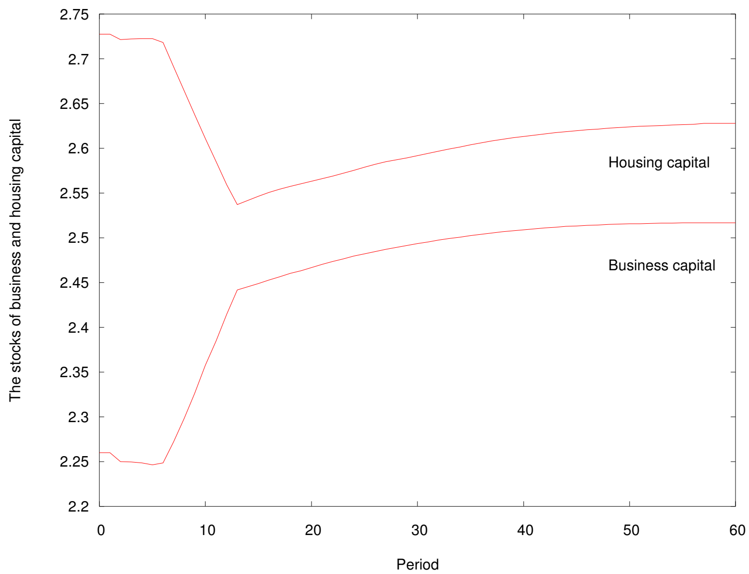
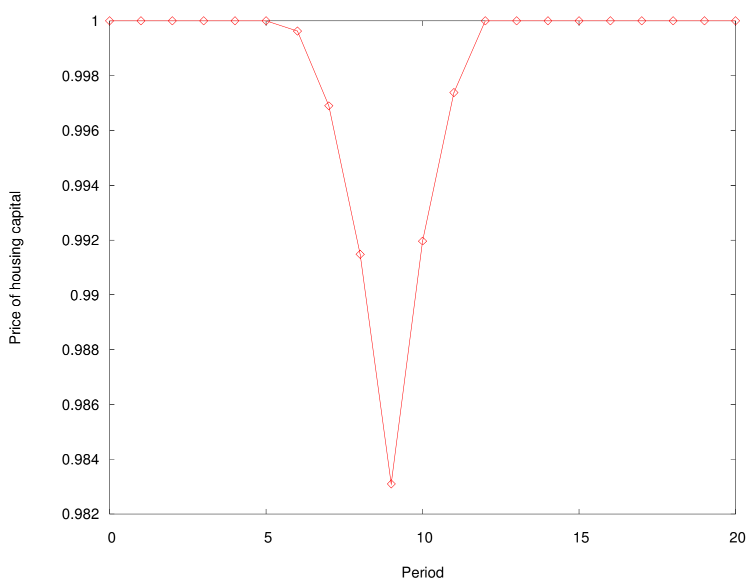


FIGURE 5. THE PRICE OF NEW HOUSING CAPITAL AFTER REFORM 3.



3.3 Distributional effects

In order to describe the distributional effects of the tax reforms, we sort households in the initial steady state distribution along two dimensions: net worth and age.[16] Specifically, we consider the net worth quintiles and (model) age groups {1-10,11-20,...,51-60} so that we have 30 different net worth-age groups. Given our demographic assumptions, the age groups correspond to real ages $\{25\text{-}35, 36\text{-}45, ..., 76\text{-}85\}$. For each of these groups, we compute the share households that are better off (the 'winners') with a tax reform in question compared to the status quo: We also consider the average welfare gain in different groups. The first example of the way we analyze the distributional effects is table 3, which presents the distribution of winners and losers of Reform 1. It tells us, for instance, that 21% of the households that are of age 1-10 and belong to the fourth net worth quintile (among all households) benefit from Reform 1. The bottom rowgives the fraction of gainers in each age group and the rightmost column shows the fraction of gainers in each wealth quintile. The rightmost cell in the bottom row gives the fraction of winners among all households alive when the reform is implemented. Empty cells in the table correspond to age-net worth groups with no households in the initial steady state distribution.

Table 3 reveals that Reform 1 makes 54% of the households in the initial steady state distribution better off compared to the status quo, while the remaining 46% would have an incentive to oppose it. The distribution of winners and losers follows a rather systematic pattern. The reform benefits most of the young households while the old households tend to be worse off. For instance, 86% of all households of model age 1-10 are better off, whereas all households of age 51-60 are worse off. The reform also tends to benefit the poor households and hurt the wealthy. Of households in the first net worth quintile, 78% are better off, whereas all households belonging to the wealthiest quintile are worse off.

[16] The sorting is done according to the net worth in the initial steady state instead of the post-reform net worth just after the announcement of a tax reform.

TABLE 3.SHARE OF WINNERS (%) OF REFORM 1.

	Age						
Net worth	1-10	11-20	21-30	31-40	41-50	51-60	Average
0-20	1.00	1.00	-	-	-	0.00	0.78
20-40	1.00	1.00	1.00	1.00	0.99	0.00	0.98
40-60	1.00	0.98	0.99	0.98	0.21	0.00	0.88
60-80	0.21	0.11	0.07	0.02	0.00	0.00	0.07
80-100	-	0.00	0.00	0.00	0.00	0.00	0.00
Average	0.86	0.68	0.56	0.46	0.34	0.00	0.54

Table 4 shows the average welfare effects in the same net worth-age groups. The average welfare gain of all households is -0.9%. The welfare effects are quite unequal across different groups. The most adversely affected households are very old households: the average welfare gain of households of model age 51-60 is -7.8%. Even relatively young but wealthy households suffer welfare losses.

TABLE 4. AVERAGE WELFARE EFFECTS (%) OF REFORM 1.

	Age						
Net worth	1-10	11-20	21-30	31-40	41-50	51-60	Average
0-20	3.3	3.6	-	-	-	-6.4	1.5
20-40	3.5	3.5	2.9	1.0	0.5	-12	2.1
40-60	1.6	1.4	2.0	1.3	-0.9	-11	0.6
60-80	-1.1	-1.8	-2.0	-2.6	-3.9	-7.7	-3.1
80-100	-	-4.2	-5.1	-5.8	-6.0	-6.9	-5.4
Average	2.4	1.2	-0.5	-2.0	-2.6	-7.8	-0.9

The distributional impact of the tax reform arises from the changes in the tax structure and general equilibrium factor return and house price effects. In order to evaluate the importance of the general equilibrium effects, we simulate the transition following Reform 1 but fixing now the interest rate, the wage rate, and house prices at their initial steady state levels. Thus, compared to the initial steady state, households only face different tax rates. Average welfare effects in different net worth-age groups are presented in table 5.

TABLE 5. AVERAGE WELFARE EFFECTS (%) OF REFORM 1; FIXED FACTOR RETURNS AND HOUSE PRICES.

	Age						
Net worth	1-10	11-20	21-30	31-40	41-50	51-60	Average
0-20	-0.9	-0.8	-	-	-	-5.1	-5.0
20-40	-0.9	-0.9	-1.3	-3.4	-3.5	-7.6	-7.6
40-60	0.9	-0.2	-2.0	-3.0	-4.2	-8.3	-8.3
60-80	0.8	-0.6	-1.6	-3.3	-5.1	-7.7	-7.6
80-100	-	-0.3	-1.9	-3.8	-6.0	-7.3	-7.4
Average	-0.4	-0.8	-1.8	-3.3	-4.6	-6.6	-2.5

The average welfare gains are now negative in most groups and the average welfare gain among all households is -2.4%. This reflects the fact that the benefits of this reform are due to the general equilibrium effects. Compared to the general equilibrium case, the distributional effect is quite different along the net worth dimension. Welfare losses of the wealthy are now in many cases smaller than the welfare losses of the poor. Very young (1-10) and relatively wealthy (40-80) households are even better off now. The rationale for this is that in a general equilibrium the interest rate falls. This hurts the rich because a large part of their expected future income is interest income.

Old households are still substantially worse off. This can be explained by the average portfolio composition over the life cycle (figure 1). Because of life cycle savings motives, old households have most of their wealth in the form of housing. Indeed, very old households choose to have no financial assets at all. Therefore, a tax reform that lowers the taxation of financial savings by taxing housing increases the total tax bill of old households. This reform does increase the net social security benefit because of a lower labor tax and an increasing wage rate. However, that is not sufficient to compensate the old households.

What is the distributional effect of the house price fall that follows the tax reform? In order to answer this question, we simulate the transition with the general equilibrium paths for factor returns and tax rates but keeping house prices constant at the steady state level. The distribution of average welfare gains is shown in table 6. Comparing table 6 with table 4 reveals that the house price fall hurts substantially the old (51-60) households. For the other groups, however, the average welfare gain is more or less unaffected.

TABLE 6. AVERAGE WELFARE GAINS (%) OF REFORM 1; FIXED HOUSE PRICES.

	Age						
Net worth	1-10	11-20	21-30	31-40	41-50	51-60	Average
0-20	3.7	3.8	-	-	-	-2.8	2.5
20-40	3.5	3.5	2.9	1.1	0.7	-5.9	2.3
40-60	1.5	1.4	2.0	1.3	-0.8	-6.8	0.1
60-80	-1.1	-1.8	-1.9	-2.6	-3.7	-6.4	-2.8
80-100	-	-4.1	-5.1	-5.7	-5.8	-6.5	-5.4
Average	2.8	1.3	-0.6	-1.9	-2.4	-4.9	-0.5

The distribution of winners and losers of Reform 2, which imposes a tax on the imputed rent while lowering only the capital income tax, is shown in table 7. The first thing to note is that the tax reform benefits only 25% of the households. Compared to Reform 1, the distributional effects are very different. Reform 2 benefits basically only the wealthiest households that are not too old. The same group of households were worse off with Reform 1. The substantial reduction in the capital income tax rate is now sufficient to compensate them for the lower interest rate. The few winners among the young and middle-aged households belonging to the first three wealth quintiles have just experienced a positive labor income shock. They are just about to increase substantially their demand for housing. Therefore, they benefit from the fall in the house price.

TABLE 7. SHARE OF WINNERS (%) OF REFORM 2.

	Age						
Net worth	1-10	11-20	21-30	31-40	41-50	51-60	Average
0-20	0.02	0.02	-	-	-	0.00	0.02
20-40	0.02	0.02	0.02	0.00	0.00	0.00	0.01
40-60	0.02	0.01	0.02	0.00	0.00	0.00	0.01
60-80	0.90	0.80	0.23	0.22	0.00	0.00	0.43
80-100	-	1.00	1.00	0.97	0.11	0.00	0.76
Average	0.17	0.32	0.40	0.38	0.03	0.00	0.25

The average welfare gains of Reform 2 are shown in table 8. The average welfare gains among all households alive in period 1 is -1.9%. Again, old households suffer the largest welfare losses. Except for the wealthiest households, the average welfare losses among the old are larger than with Reform 1. The reason is that the net pension benefit increases less than with Reform 1, because the labor income tax is now kept fixed. Young households suffer welfare losses which are about one half of the long run welfare gains presented in table 2.

TABLE 8. AVERAGE WELFARE GAINS (%) OF REFORM 2.

	Age						
Net worth	1-10	11-20	21-30	31-40	41-50	51-60	Average
0-20	-1.9	-1.8	-	-	-	-16	-4.0
20-40	-1.4	-1.6	-1.7	-3.1	-3.7	-7.2	-4.0
40-60	-0.5	-0.8	-1.8	-2.5	-3.2	-13	-2.8
60-80	0.5	0.4	0.1	-0.4	-1.9	-6.2	-1.1
80-100	-	1.3	1.4	0.7	-0.8	-3.3	0.5
Average	-1.4	-0.8	-0.6	-1.0	-2.4	-9.0	-1.9

We now discuss the distributional effects of Reform 3, where the taxation of the imputed rent is postponed by 10 periods. However, in order to limit the number of tables, we don't present the results in detail. Given that old households suffer the largest welfare losses, one might think that simply postponing these reforms by a number of years would make the welfare effects more even. This is indeed the case with Reform 3. For instance, the average welfare gain of households of age 51-60 is -0.5% (-7.8% with Reform 1). In other words, postponing the taxation of the imputed rent is a simple way of avoiding the largest welfare losses which are borne by the old households. On the other hand, the welfare gains of young and poor households are also substantially reduced. For instance, the average welfare gain of households of age 1-10 is 1.1% (2.4% with Reform 1). As a result, the average welfare gain among all households alive in period 1 increases to -0.3% (-0.9% with Reform 1) but the overall fraction of households benefiting from the reform decreases to 0.50 (0.54 with Reform 1).

Finally, we consider the distributional effects of Reform 4 which eliminates the mortgage interest deductibility. Table 9 presents the distribution of winners and losers. Only 23% of all households alive in period 1 are better off with this tax reform. Both poor and wealthy households are worse off, whereas the 'middle-class' is better off. The poor are worse off because they finance their housing with mortgages. Therefore, the removal of the mortgage interest deductibility increases their tax burden. The richest households are worse off partly because of factor price effects. The interest rate decreases and this effect lowers the net income of the wealthiest households who rely mainly on capital income.

TABLE 9. SHARE OF WINNERS (%) OF REFORM 4.

	Age						
Net worth	1-10	11-20	21-30	31-40	41-50	51-60	Average
0-20	0.02	0.02	-	-	-	0.00	0.01
20-40	0.38	0.04	0.02	0.00	0.00	0.00	0.03
40-60	0.98	1.00	0.63	0.07	0.06	0.00	0.38
60-80	0.84	0.84	0.92	0.97	0.67	0.00	0.73
80-100	-	0.00	0.05	0.03	0.00	0.00	0.02
Average	0.25	0.20	0.42	0.23	0.17	0.00	0.23

Table 10 presents the average welfare gains of Reform 4. Compared to Reforms 1 and 2, the distributional effect is more moderate in that both the largest welfare gains and losses are smaller. The average welfare gain is -1.0%. The largest welfare losses are again borne by old households: the average welfare gain of households of age 51-60 is -4.9%. This is not surprising given that old households wish to mortgage their housing.

TABLE 10. AVERAGE WELFARE GAINS (%) OF REFORM 4.

	Age						
Wealth	1-10	11-20	21-30	31-40	41-50	51-60	Average
0-20	-1.1	-0.6	-	-	-	-6.6	-2.2
20-40	0.0	-0.3	-0.5	-3.1	-3.8	-8.3	-2.5
40-60	1.6	2.0	0.5	-1.6	-1.6	-6.2	-0.9
60-80	0.8	0.8	0.8	0.7	0.2	-2.3	0.2
80-100	-	-0.8	-0.9	-0.8	-0.5	-1.0	-0.7
Average	-0.6	-0.2	-0.1	-1.0	-1.8	-4.9	-1.0

3.4 Sensitivity analysis

Our focus is on the short run effects of housing tax reforms. In this respect, an important parameter is likely to be the depreciation rate of housing capital, δ_h. Given the irreversibility assumption, it determines how fast the supply of housing can adjust downwards. We therefore reconsider Reform 1 with two different values: $\delta_h = 0.005$ and $\delta_h = 0.0609$. In both cases, we adjust the maintenance cost parameter κ so that we still have $\delta_h + \kappa = 0.0609$. This means that the steady state user cost of housing is unaffected by these changes. Hence, steady state effects of the tax reforms are the same as with the benchmark calibration.

With $\delta_h = 0.0609$, the irreversibility constraint is binding only during the first period following Reform 1. As a result, the stock of business capital jumps close to its new steady level already in period 2. The house price effect is extremely small: the price of new housing capital falls by 0.3% in period 1. The distribution of winners and losers (not shown) is similar to the benchmark case. Of all households alive in period 1, 59% are better off (54% in the benchmark case). The average welfare gain across all households alive in period 1 now increases $+0.1\%$ (-0.9% in the benchmark case). The welfare losses of very old and relatively poor households are substantially reduced compared to the benchmark case.

With $\delta_h = 0.005$, the irreversibility constraint for housing capital is binding for 12 periods and housing price first falls down to 0.91. Again the distribution of winners and losers (not shown) is similar to that in the benchmark case. The main difference is that now only 13% of households with model age 41-50 are better off with the tax reform (34% in the benchmark case). Off all households alive in period 1, 50% are now better off. Compared to the benchmark case, the average welfare gains are smaller in all groups. The average welfare gain is now -1.6%.

These results demonstrate that the average welfare effect depends on the assumptions about the elasticity of housing supply. The faster the stock of housing capital can adjust downwards, the larger is the average welfare gain. This is because of a faster transition towards the new steady state with a higher business capital stock. However, the distributional effects seem to be quite similar with different assumptions about housing supply.

4 Conclusions

We have analyzed the effects of alternative tax reforms which all reduce the current tax benefits of owner housing. The simple tax reforms we considered would make many households worse off with smaller groups suffering substantial welfare losses. In this sense, the results are consistent with the notion that it is politically difficult to tax housing and should therefore help to understand the political disussion around housing's tax status. On the other hand, they may also be helpful in the design of broader and politically feasible tax and benefit reforms involving housing.

A Computational issues

It is helpful to divide the household's problem into a static and an intertemporal one. Given the individual state and tomorrow's net worth, say y', the static problem is

$$\max_{c,a',m',h'} u(c,h')$$

subject to (11) -(13). This problem can be further split into two cases. First, assume that $a'=0$ and $m'\geq 0$. Use (12) to solve for h' as a function of c, say $h'=x(c)$. Then determine the optimal c from the first-order condition: $u_c+u_h x'(c)=0$. Next, assume that $m'=0$ and $a'\geq 0$ and solve again for the optimal c. Out of these two solutions, the one that yields a higher utility is the solution to the static problem.

Denoting the optimal consumption and housing choices from the above problem by $c_{y,y'}$ and $h_{y,y'}$, the intertemporal problem is then

$$V(y,\xi,j)=\max_{y'}\{u(c_{y,y'},h_{y,y'})+\beta\psi_j E_{\xi'|\xi}V(y',\xi',j+1)\}.$$

We discretize the state-space in the net worth dimension and interpolate the value for points between gridpoints. We aggregate the economy by following step densities defined over a net worth grid.

The transition is solved by first guessing a smooth transition path for all relevant aggregate variables from the initial steady state to the new one, solving the household problem for all cohorts that alive at some point during the transition, aggregating the economy, and then updating the guess. This needs to be repeated until the guess has converged. We find the equilibrium house price in the following way. In the first iteration, we guess that $p_t^n=1$, for all t. Aggregating households' policies, we obtain housing demand for each period, say H_t^d. For each period t, we then construct 'housing supply', H_t^s as follows. If $p_t^n=1$ and $H_t^d\geq(1-\delta_h)H_{t-1}^d$, then $H_t^s=H_t^d$. If $p_t^n=1$ and $H_t^d<(1-\delta_h)H_{t-1}^d$ then $H_t^s=(1-\delta_h)H_{t-1}^d$. If $p_t^n<1$, then $H_t^s=(1-\delta_h)H_{t-1}^d$. We can then define 'excess supply' as $H_t^{es}=H_t^s-H_t^d$ and obtain a new guess for the house price sequence by adjusting the price of housing capital in a given period downwards with a factor that depends proportionally on the excess supply in the same period.

As explained above, one complication here is that the initial steady state net worth, together with ξ and j, is not a sufficient state variable when looking at household's problem in the reform period. For the first period after the tax reform is announced, we have to recover their portfolio choices from the previous period (or from the initial steady state). This allows us to determine households' new net worth which together with their labor income shock and age determines their individual states. Also, we have to fix the lower bound of the net worth grid at a value below zero, even though we impose a non-negativity constraint on tomorrow's net worth in the household's problem. This is because an unexpected tax reform may well lower the net worth of some households below zero and we need to be able to simulate their behavior following the tax reform.[17] This is not a problem as long as the left hand side of the budget constraint (11) is positive. This was always the case in the simulations that are reported here.

[17]Note that this means also that some households may leave negative accidental bequests in the reform period.

References

[1] Berkovec, James and Don Fullerton (1992), "A General Equilibrium Model of Housing, Taxes, and Portfolio Choice," *Journal of Political Economy* 100(2), 390-429.

[2] Bruce, Donald and Douglas Holtz-Eakin (1999), "Fundamental Tax Reform and Residential Housing," *Journal of Housing Economics* 8(4), 249-71.

[3] Conesa, Juan C. and Dirk Krueger (1999), "Social Security Reform with Heterogenous Households," *Review of Economic Dynamics* 2, 757-795.

[4] Díaz-Giménez, Javier, Vinzenzo Quadrini, and José-Victor Ríos-Rull (1997), "Dimensions of Inequality: Facts on the U.S. Distributions of Earnings, Income, and Wealth," *Federal Reserve Bank of Minneapolis Quarterly Review,* Spring.

[5] Fullerton, Don (1987), "The Indexation of Interest, Depreciation, and Capital Gains and Tax Reform in the United States," *Journal of Public Economics* 32(1), 25-52.

[6] Gahvari, Firouz (1985), Taxation of housing, capital accumulation, and welfare: a study in dynamic tax reform, *Public Finance Quarterly* 13(2), 132–160.

[7] Gervais, Martin (2002), "Housing Taxation and Capital Accumulation," *Journal of Monetary Economics* 49(7), 1461-1489.

[8] Greenwood, Jeremy, Richard Rogerson, and Randall Wright (1995), "Household Production in Real Business Cycle Theory," in Thomas F. Cooley, ed., Frontiers of Business Cycle Research. Princeton: Princeton University Press.

[9] Hendershott, Patric H. and Michael White (2000), "Taxing and Subsidizing Housing Investment: The Rise and Fall of Housing's Favored Status," *Journal of Housing Research* 11(2), 257-275.

[10] İmrohoroğlu, Ayşe, Selahattin İmrohoroğlu, and Douglas H. Joines (1995), "A life cycle analysis of social security," *Economic Theory* 6(1), 83-114.

[11] Laidler, David (1969), "Income tax incentives for owner-occupied housing," in A. Harberger and M.J. Bailey, eds., The taxation of income from capital. Washington, DC: The Brookings Institution, 1969.

[12] Poterba, James M. (1984), "Tax Subsidies to Owner-occupied Housing: An Asset-Market Approach," *The Quarterly Journal of Economics* 99 (4), 729-52.

[13] Poterba, James M. (1992), "Taxation and Housing: Old Questions, New Answers," *American Economic Review* 82(2), 237-42.

[14] Rosen, Harvey S. (1985), "Housing subsidies: Effects on Housing Decisions, Efficiency, and Equity," Handbook of Public Economics Vol. 1, 375-420.

[15] Skinner, Jonathan (1996), "The Dynamic Efficiency Cost of Not Taxing Housing," *Journal of Public Economics* 59(3), 397-417.