The Taxpayer Relief Act of 1997 and the U.S. Housing Boom*

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Abstract

In the period 1997-2007, the following developments took place in the U.S. residential housing market. First, house prices and mortgage volume increased strongly, but mortgage volume increased faster than house prices so that the loan-to-value ratio increased. Second, delinquency rates fell. We use a calibrated macro model to argue that the Taxpayer Relief Act of 1997, which eliminated taxes on capital gains from the sale of residential housing for most households, can account for a substantial part of these developments in the U.S. housing market. With higher after-tax gains from the purchase of housing, agents are less likely to default on their mortgages which increases both the demand and supply of credit for housing and hence helps us understand the simultaneous increase in the loan-to-value ratio and decline in mortgage default rates observed over the period 1997-2007.

Keywords: Housing Market, Default Risk, Tax Policy
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1 Introduction

In the period from the mid 1990s until the beginning of the housing crisis, the U.S. housing market experienced a number of remarkable developments. First, house prices and mortgage volume increased strongly, but mortgage volume grew faster than house prices so that the aggregate loan-to-value ratio increased. Specifically, between 1997 and 2007, real house prices went up by 55% percent (see Figure 1.A), the mortgage-to-GDP ratio went up from 44% to 74% (see Figure 2.A), and the loan-to-value ratio increased from 55% to 70% (see Figure 2.B). Second, in the same period delinquency rates dropped significantly (see Figure 3). In this paper, we ask two questions. First, did the U.S. Taxpayer Relief Act of 1997 contribute to these developments? Second, to what extent could some of these developments have been dampened by a different type of tax reform?

To address these questions, we develop a macro model with a housing sector and conduct a quantitative analysis of the tax reform based on a calibrated version of the model economy. In the model, households can buy consumption goods, save in a risk-free asset, rent or invest in housing space, and invest in human capital. Housing investment and human capital investment are subject to uninsurable idiosyncratic risk. Households can also borrow and default on their debt, in which case they lose their housing investment and are excluded from borrowing for a number of periods (mortgage default with foreclosure and limited access to mortgage markets in the future). Household are ex-ante heterogeneous with respect to age (life-cycle) and their preferences for housing. We close the model assuming a fixed supply of housing (land) and an aggregate production function that displays constant returns to scale with respect to physical capital and human capital. The second assumption implies that the model generates endogenous growth.

The U.S. Taxpayer Relief Act of 1997 eliminated the capital gains tax on housing sales for all households if the gains did not exceed \$500,000 (for single households \$250,000). In contrast, before the tax reform in 1997 households could only avoid the capital gains tax if they re-invested the gains in larger homes. In other words, before the tax reform the capital gains tax had to be paid in all cases in which households do not want to increase their housing investment, which are most likely cases of job loss, divorce, or illness. Thus, the U.S. Taxpayer Relief Act of 1997 not only increased the after-tax expected return to housing investment, but also reduced the risk associated with housing investment. When we feed the tax changes associated with the U.S. Taxpayer Relief Act of 1997 into the calibrated model economy, we find the following results.

First, the model predictions are qualitatively in line with the main developments in the U.S. housing market: house prices and mortgage volume rise, but mortgage volume rises faster than house prices so that loan-to-value ratios (leverage) increase. Second, the effects are quantitatively important, but the predicted changes are substantially less than the changes observed in the period 1997-2007. Specifically, according to our simulations

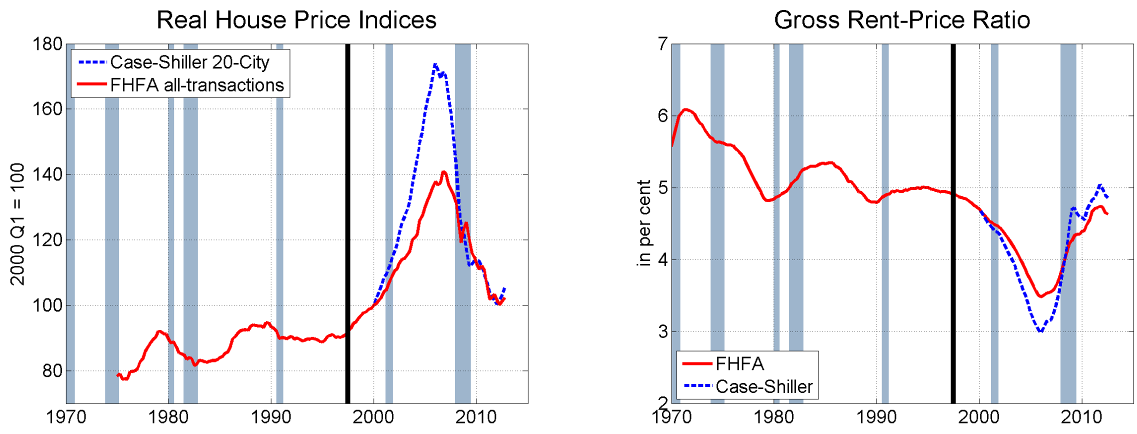

Figure 1: House prices and rent-price ratio for the U.S.
NOTES: Nominal values are deflated using the CPI for All Urban Consumers: All items less shelter. The shaded regions correspond to NBER-recessions.
SOURCE: FRED / FHFA; Davis, Lehnert, and Martin (2008), updated data:
http://www.lincolninst.edu/subcenters/land-values/rent-price-ratio.asp

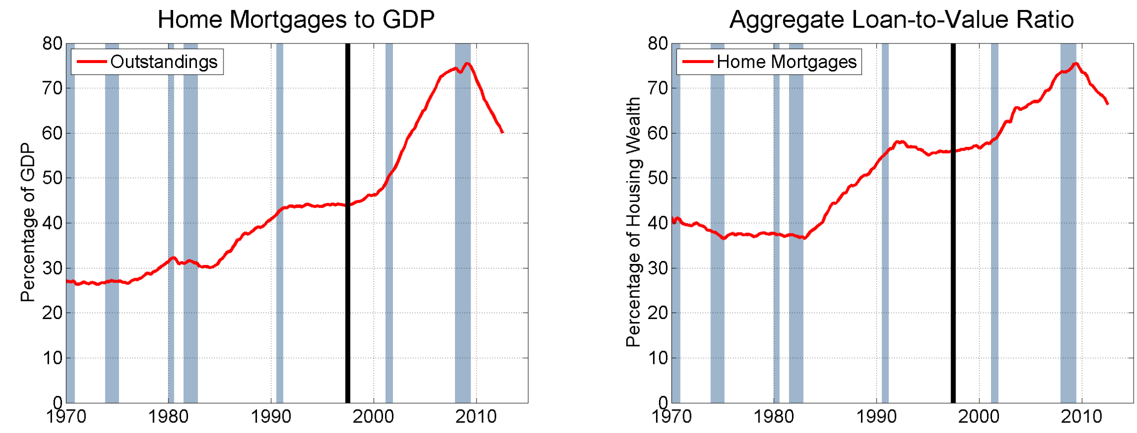

Figure 2: Home Mortgage Debt
NOTES: The shaded regions correspond to NBER-recessions.
SOURCE: FRED, Flow-of-Funds and NIPAs

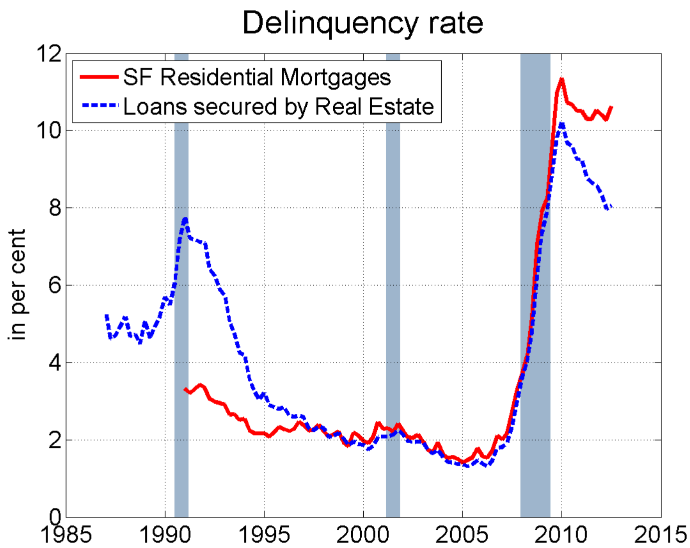

Figure 3: Mortgage Delinquencies
NOTES: The shaded regions correspond to NBER-recessions.
SOURCE: FRED

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the U.S. Taxpayer Relief Act of 1997 increased real house prices by 6.4 percent, increased the mortgage-to-GDP ratio from 44.0% to 49.0%, and increased the loan-to-value ratio from 55.7% to 58.2%. Thus, our conclusion from this analysis is that the U.S. Taxpayer Relief Act of 1997 can account for some part of the U.S. housing boom, but the larger part, in particular the strong increase in house prices, has to be explained by other factors (i.e. low interest rates and/or financial innovation).

We also find that the U.S. Taxpayer Relief Act of 1997 reduced mortgage default rates. In our model economy, a reduction in the housing tax has two opposing effects on equilibrium default rates. On the one hand, the tax reduction leads to higher housing leverage and therefore higher mortgage default rates. On the other hand, the tax reduction also makes mortgage default more costly since exclusion from mortgage markets becomes more costly. In our calibrated model economy, the second effect dominates and we therefore find that the U.S. Taxpayer Relief Act of 1997 decreased mortgage default rates. The prediction of a simultaneous rise in loan-to-value ratios and decline mortgage default rates distinguishes our work from previous macro work on housing, which assumes that the only consequence of default is the loss of the housing investment (foreclosure) and therefore necessarily predicts that leverage and default rates are positively correlated.

We also consider the effect of a hypothetical tax reform that taxes capital gains on housing sales at the same rate that all other capital gains are taxed without any exemptions. We find that this tax reform would have reduced real house prices by 4.1 percent, the mortgage-to-GDP ratio from 44.0% to 41.5%, the loan-to-value ratio from 55.7% to

54.7%. Thus, if this tax reform had been implemented in 1997, instead of the Taxpayer Relief Act of 1997, our analysis suggests that real house prices would have been 10.5 percent lower than their actual value. In other words, implementing a tax reform that treats capital gains of housing sales as ordinary capital gains as opposed to the Taxpayer Relief Act of 1997 would have dampened the observed house price rise during the U.S. housing boom by about 20 percent.

1.1 Related Literature

We build on the growing macro literature that uses calibrated model economies to conduct a quantitative analysis of the housing sector. We make two contributions to this literature. First, on the substantive side we contribute to the literature that studies the positive (and normative) consequences of government housing policy. In this respect our paper is closely related to the work of Gervais (2002), who studies the effects of preferential tax treatment of housing, Jeske, Krueger, and Mitman (2013), who evaluate the effects of the government bailout guarantees for Government Sponsored Enterprises, and Nakajima (2010), who studies the optimal income tax rate when residential capital is treated preferentially in the tax code. Chambers, Garriga, and Schlagenhauf (2014) analyze to what extent U.S. housing policy caused the postwar boom in homeownership. We contribute to this literature by analyzing a major tax reform, namely the Taxpayer Relief Act of 1997, which has so far not been studied by the macro literature.

Our second contribution is to develop a model with mortgage debt and default in which mortgage interest rates reflect equilibrium default probabilities and the consequences of default are twofold: mortgage default leads to loss of housing investment (foreclosure) and limited access to mortgage markets in the future. In this regard, our work is a natural extension of the literature on uncollateralized debt and equilibrium default (Chatterjee, Corbae, Nakajima, and Ríos-Rull, 2007; Livshits, MacGee, and Tertilt, 2010). In contrast, the existing housing literature has incorporated equilibrium mortgage rates that fully reflect default probabilities (Chatterjee and Eyigungor, 2011; Corbae and Quintin, 2013; Jeske, Krueger, and Mitman, 2013), but has so far confined attention to the case in which mortgage default has no repercussions on the ability of households to borrow in the future (however, see also Mitman (2012) for a noteworthy exception). As we have argued above, this extension is important to understand any historical episode in which leverage rises and default rates are either constant or declining.

Finally, our paper is related to empirical work evaluating the effects of the Taxpayer Relief Act of 1997. Consistent with our results, this literature has found that during the pre-reform period many homeowners were prevented from selling their homes due to capital gains taxation, and that the Taxpayer Relief Act of 1997 has released these lock-in effects (Biehl and Hoyt, 2014; Cunningham and Engelhardt, 2008; Heuson and Painter, 2014; Shan, 2011). Indeed, we use the estimates of this literature to calibrate our model economy along one important dimension. We complement this literature by analyzing the effects on aggregate house prices, mortgage volume, and default rates in an equilibrium model.

2 Model

2.1 Economy

2.1.1 Household sector

The economy is populated by a unit mass of households. Households age stochastically according to a Markov process with transition probability $\pi(j'|j)$. We consider three age-groups j: young, middle-aged, and old. Old people stochastically die and are immediately replaced by newborns. For each age group there are two subgroups with low and high housing return, respectively. Households move from housing return state L to H – i.e. become first-time buyers – with probability b_j. In addition, we distinguish middle-aged households with high human capital return (type $m1$) and middle-aged with low human capital return (type $m2$). In sum, there are 2*4 types of households denoted by $\{y, m1, m2, o\} \times \{H, L\}$, with type transitions specified by transition matrix Π^T (for details see Appendix A.1). We assume that the demographic structure of the population is stationary.

Households derive utility from consumption of two goods: a standard good and housing services. We assume that households have identical time-separable preferences which can be represented by the discount factor β and the following one-period utility function

$$u(c_1, c_2) = \begin{cases} \ln c_1 + \nu \ln c_2 & if\ no\ default \\ \ln c_{d1} + \nu \ln c_{d2} - u_d & if\ in\ default \end{cases} \tag{1}$$

where c_1 is consumption of the standard good, c_2 is consumption of the housing service, and u_d is a utility cost of being in default. Households can invest in human capital h, physical capital k, and housing x. We assume that households do not care whether they live in a rented home or owner-occupied home. Besides, they can take out an one-period mortgage m. Actually, they choose mortgages from a menu that states loan-to-value ratios $\ell' = \frac{p_m m'}{\tilde{p}_x x'}$ and corresponding mortgage prices p_m. The standard consumption good can be transformed one-to-one into physical capital or human capital, whereas the housing stock is in fixed supply. Thus, the sequential budget constraint for a household who is not in default reads

$$
\begin{aligned}
& c_1 + \tilde{p}_l c_2 + k' + h' + p_m m' + \tilde{p}_x x' \; = (1+tr) \cdot \\
& [(1 + \tilde{r}_k - \delta_k)k + (1 + \tilde{r}_h(j) - \delta_h + \eta(s))h + m + [\tilde{p}_l + (1+\epsilon(s))\tilde{p}_x - \tau(s)\tilde{p}_x]\, x] \\
& h' \geq 0 \;, k' \geq 0 \;,\; x' \geq 0 \;,\; m' \leq 0
\end{aligned}
\tag{2}
$$

where we used the following variable definition:

h, k, x: stock of human capital, physical capital, and housing owned by household

$\tilde{r}_h(j)$, $\tilde{r}_k$: rental rate of human capital, physical capital

$\tilde{p}_x$: aggregate price of housing

$\tilde{p}_l(j)$: price of housing services

$\epsilon(s)$: idiosyncratic shock to the price of housing

$\tau(s)$: capital gains tax on the sale of housing

m: mortgage (quantity)

p_m: price of mortgage

$\eta(s)$: idiosyncratic human capital shock

tr: transfer rate

s: exogenous state

We assume that the human capital shock η to is normally distributed with zero mean. In the following, however, we consider a discrete-state approximation. In contrast, the individual house price shock ϵ is uniformly distributed on the support $[\epsilon_{min}; \epsilon_{max}]$.

In addition to the choice of $(k', h', m', x', c_1, c_2)$ households also make a default decision, which in general depends on the entire state (k, h, m, x, s). However, in our setting, the current default decision depends only on the current stock of housing x and mortgage debt m as well as current shocks s. Thus, a default policy is a function $d = d(x, m, s, j)$ mapping current shocks into $\{0, 1\}$ where 1 stands for default.

We model the consequences of default as follows. All debt is canceled and the housing collateral is seized.[1] However, there is no garnishment of wage income. Besides, the household who defaults is excluded from the mortgage market in future. By this, we mean the household can neither take on any debt nor buy a house. Nevertheless, he can invest into physical and human capital. In sum, the budget constraint for households in default is given by (2) with $m = x = 0$ and the restriction $m' = x' = 0$. We assume that the period of exclusion ends stochastically with probability $1 - p$. As long as the household is in default, he suffers a utility cost of u_d.

[1] If the household decides to default, he loses, by assumption, all his housing assets in foreclosure, even if he is not under water.

2.1.2 Financial intermediaries

Financial intermediaries borrow at the risk-free rate $r_f = \tilde{r}_k - \delta_k$ and incur a real resource cost of financial intermediation $\Delta \geq 0$ per unit of the mortgage. We assume that financial intermediaries can observe the loan-to-value ratio ℓ of the mortgages they offer. However, they do not observe default policies and, hence, cannot condition the mortgage price p_m on it. Hence, a mortgage is represented by the pair (p_m, ℓ'). In case of default the mortgage claim m' is written off and the housing collateral x' is liquidated. We assume that financial intermediaries possess a foreclosure technology according to which they recover a fraction $\gamma \leq 1$ of the current market value of the foreclosed home $(1+\epsilon')p'_x x'$.[2] Besides, we assume for simplicity that there are no capital gains taxes on foreclosed homes.

Financial intermediaries offer various types of mortgages, i.e. combinations of loan-to-value ratios and mortgage prices. We assume that financial intermediaries can fully diversify idiosyncratic risk for each mortgage type (p_m, ℓ') and all mortgage markets are perfectly competitive so that they earn zero profits on each mortgage type. Zero profit per mortgage type requires that the intermediary exactly earns its costs of funding $1 + r_f + \Delta$. Hence, the mortgage pricing schedule $p_m(\ell')$ is given by

$$(3) \qquad 1/p_m = max \left\{ \frac{1 + r_f + \Delta - \gamma \cdot \frac{\tilde{p}'_x}{\tilde{p}_x} \frac{1}{\ell'} \left(1 + E[\epsilon' | d_{max} = 1]\right)}{1 - E[d_{max} = 1]}, \; 1 + r_f + \Delta \right\}$$

where $E[d_{max} = 1]$ is the expected default rate for this mortgage contract.

2.1.3 Production and Housing Supply

We assume that the non-housing good is produced under the production function $Y = AK^{\alpha}H^{1-\alpha}$, where K is the aggregate stock of physical capital, H the aggregate stock of human capital, and A a productivity parameter. Markets for physical and human capital are perfectly competitive so that the rental rates satisfy

$$(4) \qquad \begin{aligned} \tilde{r}_k &= \alpha A \tilde{K}^{\alpha-1} \\ \tilde{r}_h &= (1-\alpha) A \tilde{K}^{\alpha} \end{aligned}$$

where $\tilde{K} = K/H$ denotes the capital-to-labor ratio. While the non-housing consumption good can be transformed one-to-one into physical capital or human capital, the housing stock is in fixed supply, normalized to one. We assume that one unit of the housing stock generates one unit of housing consumption services. We further assume that mortgages are financed through savings from abroad. Thus, we have three market clearing conditions

[2] If the net revenue from foreclosure exceeds the size of the mortgage m', the bank is repaid and the excess amount vanishes by assumption.

that read:

$$\tilde{K} = \frac{\sum_i E[k^i|j=i]\pi(i)}{\sum_i E[h^i|j=i]\pi(i)}$$
$$1 = \sum_i E[x^i|j=i]\pi(i) \tag{5}$$
$$1 = \sum_i E[c_2^i|j=i]\pi(i)$$

where $\pi(i)$ is the population share of household type i. Note that the first market clearing condition in (5) follows from combining the market clearing conditions for physical capital and human capital. The second condition is market clearing for the housing stock and the third is for housing services. Finally, goods market clearing is implied by Walras' law and the aggregate stock of mortgage debt amounts to $M = \sum_i E[m^i|j=i]\pi(i)$.

2.1.4 Government

The government collects income taxes. The U.S. law of taxation distinguishes ordinary income, which includes wage income, from long-term capital gains. However, in the U.S. there have been several tax breaks for owner-occupied housing.[3]

This paper focuses on special provisions for the recognition of capital gains from the sale of a primary residence and studies the changes that were implemented by the Taxpayer Relief Act of 1997 (TRA97). Consequently, we model the taxation of capital gains from the sale of housing in detail and abstract from ordinary income taxes and standard capital gains taxes.[4] Before the TRA97, the recognition of capital gains from the sale of a primary residence could be deferred in case the taxpayer bought a new residence of at least equal value. In this case, the capital gain would have been rolled-over into the new home. Otherwise, the gain was subject to capital gains taxation. The Taxpayer Relief Act of 1997 replaced this roll-over rule by an exemption of \$500'000 per married couple. As a consequence, since 1997 capital gains on housing have been de facto tax-exempt for the vast majority of U.S. households.[5]

We model the pre-TRA97 tax law as follows: first, we assume that a household sells his home with exogenous probability $Prob(\chi = 1) = \varsigma$. Second, capital gains from the sale of housing are taxed only if the house is downsized. In our model, this corresponds to a negative realization of the labor shock η. The following tax function which specifies the

[3]For a brief history of the U.S. law of taxation focussing on owner-occupied housing see Appendix B.

[4]However, in the quantitative analysis we calibrate the model to after-tax returns.

[5]According to the Office of Management and Budget (1997, p. 46) *"the proposal would exempt over 99 percent of home sales from the capital gains tax and would dramatically simplify taxes and record keeping for over 60 million homeowners."* Evidence by Shan (2011) supports this claim: using transaction data for the Boston metropolitan area, Shan (2011) imputes accumulated housing capital gains and finds that prior to the TRA97 only 1% of transactions have imputed capital gains over \$500'000.

tax liability per unit of housing in case of a sale captures this interpretation of roll-over:

$$(6) \qquad \tau(s) = \begin{cases} \bar{\tau} \cdot \max\left\{\frac{(1+\epsilon)\tilde{p}_x}{\tilde{p}_{x0}} - 1 \; ; \; 0\right\} & if \; \chi = 1 \;\; and \; \eta < 0 \\ 0 & otherwise \end{cases}$$

where $(1+\epsilon)\tilde{p}_x$ is the individual sales price and $\tilde{p}_{x0}$ denotes the purchase price of the home. For simplicity, we assume that the house-buying took place $1/\varsigma$ periods ago so that the the individual purchase price was $\tilde{p}_{x0} = \tilde{p}_x/(1+g)^{1/\varsigma}$. For future reference, denote the threshold level of the house price shock that implies zero capital gains on housing by $\bar{\epsilon}$, i.e. $(1+\bar{\epsilon})\tilde{p}_x/\tilde{p}_{x0} - 1 = 0$.

In equilibrium housing tax revenues amount to

$$\begin{aligned} (7) \qquad Tax &= \varsigma \cdot \sum_i E[\tau(s) \cdot \tilde{p}_x x^i | j = i]\pi(i) \\ &= \varsigma\bar{\tau} \cdot Prob(\eta < 0) \cdot \left(\int_{\bar{\epsilon}}^{\epsilon_{max}} \frac{(1+\epsilon)\tilde{p}_x}{\tilde{p}_{x0}} d\pi(\epsilon) - 1 \right) \cdot \tilde{p}_x \end{aligned}$$

where the last line uses the market clearing condition for the housing stock (5) and the tax function (6). The government rebates its tax revenues as transfers to households in order to run a balanced budget. Suppose these transfers are proportional to household wealth after all assets have paid off $(1+\tilde{r}_k-\delta_k)k + (1+\tilde{r}_h-\delta_h+\eta(s))h + m + [\tilde{p}_l + (1+\epsilon(s))\tilde{p}_x - \tau(s)\tilde{p}_x]\, x$ and denote the transfer rate by tr. Then the government's budget constraint reads

$$(8) \quad Tax = tr \cdot [(1+\tilde{r}_k-\delta_k) \cdot K + (1+\tilde{r}_h-\delta_h) \cdot H + M + (\tilde{p}_l+\tilde{p}_x) \cdot 1 - Tax]$$

where we again use the market clearing conditions (5). Hence, the balanced budget policy determines the equilibrium transfer rate.

2.2 Theoretical Results

In this section, we derive the main theoretical results. Proposition 1 characterizes the optimal decision rules of the household. Proposition 2 decribes the stationary competitive equilibrium of the model economy.

2.2.1 Characterization of Household Problem

First, note that optimality requires that consumption expenditures on goods and housing services are proportional so that the demand for housing consumption is $c_2 = \frac{\nu}{\tilde{p}_l} c_1$. This implies that total consumption expenditures are $c = c_1 + \tilde{p}_l c_2 = (1+\nu)c_1$.

Second, due to homothetic preferences and a linear-homogenous budget, the consumptionsaving decision will be independent from the portfolio choice problem which makes the model highly tractable. In the following, we will derive this separation property. To this end, it is convenient to express the household's decision problem as a portfolio choice problem. Thereto, define the following variables:

$$
\begin{aligned}
& w = h + k + p_{m,-1}m + \tilde{p}_{x,-1}x \\
& \theta_k = \frac{k}{w} \ , \ \theta_h = \frac{h}{w} \ , \ \theta_m = \frac{p_{m,-1}m}{w} \ , \ \theta_x = \frac{\tilde{p}_{x,-1}x}{w} \\
& \theta = (\theta_k, \theta_h, \theta_x, \theta_m) \\
& r_k = \tilde{r}_k - \delta_k \\
& r_h(s,j) = \tilde{r}_h(j) - \delta_h + \eta(s) \\
& r_m(\theta, s, j) = \begin{cases} \frac{1}{p_{m,-1}(\theta)} - 1 & if \ d(x,m,s,j) = 0 \\ -1 & if \ d(x,m,s,j) = 1 \end{cases} \\
& r_x(s,j) = \begin{cases} \frac{(1+\epsilon(s))\tilde{p}_x + \tilde{p}_l(j)}{\tilde{p}_{x,-1}} - 1 - \tau(s) & if \ d(x,m,s,j) = 0 \\ -1 & if \ d(x,m,s,j) = 1 \end{cases} \\
& r(\theta, s, j) = \theta_k r_k + \theta_h r_h(s,j) + \theta_m r_m(\theta, s, j) + \theta_x r_x(s,j) \\
& p_x = \frac{\tilde{p}_x}{W} \\
& p_l = \frac{\tilde{p}_l}{W}
\end{aligned}
$$

where p_{-1} is the price one period before the current period and $W = E[w]$ is aggregate total wealth. Let the law of motion for aggregate wealth be

$$
W' = (1+g)W \tag{9}
$$

where the growth rate g has to be determined later on. Using this notation, the budget constraints become

$$
\begin{aligned}
w' &= (1 + r(\theta, s, j, d))(1 + tr)w - (1+\nu)c_1 \\
1 &= \theta'_k + \theta'_h + \theta'_m + \theta'_x \\
& \quad \theta'_h \geq 0 \, , \theta'_k \geq 0 \ , \ \theta'_x \geq 0 \ , \ \theta'_m \leq 0
\end{aligned} \tag{10}
$$

and, for households in default,

$$
\begin{aligned}
w'_d &= (1 + r_d(\theta, s, j))(1 + tr)w_d - (1+\nu)c_{d1} \\
1 &= \theta'_k + \theta'_h \\
& \quad \theta'_h \geq 0 \, , \theta'_k \geq 0
\end{aligned} \tag{11}
$$

where the portfolio return for households in default is $r_d(\theta, s, j) = r(\theta_k, \theta_h, 0, 0, s, j)$.

The recursive formulations of the household maximization problems read:

$$
\begin{aligned}
V(w,\theta,s,j,W) \quad &= \quad \max\left\{ \max_{w',\theta',c_1}\left\{\nu\ln(\nu/\tilde{p}_l)+(1+\nu)\ln c_1+\beta\sum_{j'}\sum_{s'}V(w',\theta',s',j',W')\pi(s')\pi(j'|j)\right\};\right. \\
(12) \qquad & \qquad \left. \max_{w',\theta'_d,c_1}\left\{\nu\ln(\nu/\tilde{p}_l)+(1+\nu)\ln c_1+\beta\sum_{j'}\sum_{s'}V_d(w',\theta'_d,s',j',W')\pi(s')\pi(j'|j)\right\}\right\}
\end{aligned}
$$

subject to the budget constraint (10), the mortgage pricing schedule (3),[6] and the aggregate law of motion (9);

$$
\begin{aligned}
V_d(w_d,\theta_d,s,j,W) \quad &= \quad \max_{w',\theta'_d,c_{d1}}\left\{\nu\ln(\nu/\tilde{p}_l)+(1+\nu)\ln c_1-u_d+\beta p\sum_{j'}\sum_{s'}V_d(w'_d,\theta'_d,s',W')\pi(s')\pi(j'|j)\right. \\
(13) \qquad & \qquad \left. +\beta(1-p)\sum_{j'}\sum_{s'}V(w'_d,\theta'_d,s',W')\pi(s')\pi(j'|j)\right\}
\end{aligned}
$$

subject to the constraints (11) and (9) where $\theta_d=(\theta_k,\theta_h,0,0)$ and there is no disutility u_d in the period of default.

Appendix A.2 derives the solution to these Bellman equations. The value functions are logarithmic and separable:

$$
\begin{aligned}
(14) \quad V(w,\theta,s,j,W) \quad &= \quad \tilde{V}_0(j)+\frac{1+\nu}{1-\beta}\left[\ln(1+r(\theta,s,j,d(s,j)))+\ln w\right]+\frac{\nu}{1-\beta}\ln W \\
V_d(w_d,\theta_d,s,j,W) \quad &= \quad \tilde{V}_{0d}(j)+\frac{1+\nu}{1-\beta}\left[\ln(1+r_d(\theta_d,s,j))+\ln w_d\right]+\frac{\nu}{1-\beta}\ln W
\end{aligned}
$$

where $\tilde{V}_0(j),\tilde{V}_{0d}(j)$ are type-specific constants (see Appendix A.2). Consumption policies are linear in wealth:

$$
\begin{aligned}
(15) \qquad c_1 \quad &= \quad \frac{1-\beta}{1+\nu(1-\beta)}\left(1+r(\theta,s,j,d)\right)(1+tr)\cdot w \\
c_{d1} \quad &= \quad \frac{1-\beta}{1+\nu(1-\beta)}\left(1+r_d(\theta_d,s,j)\right)(1+tr)\cdot w_d
\end{aligned}
$$

$$
\begin{aligned}
(16) \qquad c_2 \quad &= \quad \frac{\nu(1-\beta)}{\tilde{p}_l\cdot(1+\nu(1-\beta))}\left(1+r(\theta,s,j,d)\right)(1+tr)\cdot w \\
c_{d2} \quad &= \quad \frac{\nu(1-\beta)}{\tilde{p}_l\cdot(1+\nu(1-\beta))}\left(1+r_d(\theta_d,s,j)\right)(1+tr)\cdot w_d
\end{aligned}
$$

[6] While households take the pricing function (3) into account, they ignore the effect of their individual default policy on the mortgage price $p_m(\ell)$. That is, they take the default probability $E[d_{max}=1]$ and the expected house price shock under default $E[\epsilon'|d_{max}=1]$ as given.

The laws of motion for wealth are linear, too:

$$
\begin{aligned}
w' &= \frac{\beta}{1+\nu(1-\beta)} \cdot (1+tr) \cdot (1+r(\theta,s,j,d)) \cdot w \\
w'_d &= \frac{\beta}{1+\nu(1-\beta)} \cdot (1+tr) \cdot (1+r_d(\theta_d,s,j)) \cdot w_d
\end{aligned} \tag{17}
$$

The optimal portfolio choices, $\theta'_{max}, \theta'_{d,max}$, are independent of wealth. For given default policy d', the portfolio choices are the solution to

$$
\begin{aligned}
\theta'_{max}(j) &= \arg\max_{\theta'} \sum_{j'} \sum_{s'} \ln\left(1+r(\theta'(j),s',j',d')\right)\pi(s')\pi(j'|j) \\
&\quad \text{subject to (3)} \\
\theta'_{d,max}(j) &= \arg\max_{\theta'_d} \sum_{j'} \sum_{s'} \ln\left(1+r_d(\theta'_d(j),s',j')\right)\pi(s')\pi(j'|j)
\end{aligned} \tag{18}
$$

Recall that, being excluded from mortgage markets, households in default have less investment opportunities than households not in default. Hence, their portfolio return will be lower: $r_d(\theta_{d,max}(j),s,j) \leq r(\theta_{max}(j),s,j,d)$. And the optimal default policy $d_{max}(\theta_x,\theta_m,s,j)$ is described by the following inequality

$$
\begin{aligned}
& \beta\frac{1-\beta}{1+\nu}\sum_{j'}[\tilde{V}_0(j') - \tilde{V}_{0d}(j')]\pi(j'|j) \\
+ \;& \beta\sum_{j'}\sum_{s'}\ln(1+r(\theta_{max}(j),s',j',d_{max}(\theta'_x,\theta'_m,s',j')))\pi(s')\pi(j'|j) \\
- \;& \beta\sum_{j'}\sum_{s'}\ln(1+r_d(\theta_{d,max}(j),s',j'))\pi(s')\pi(j'|j)] \\
\geq \;& \ln(1+r(\theta,s,j,1)) - \ln(1+r(\theta,s,j,0))
\end{aligned} \tag{19}
$$

which has to hold for all states (θ_x,θ_m,s,j) with no default, $d(\theta_x,\theta_m,s,j)=0$, given the current portfolio state θ and next-period optimal portfolio choice θ'_{max}. And for all states (θ_x,θ_m,s,j) with default, $d(\theta_x,\theta_m,s,j)=1$, the reversed inequality is satisfied. The condition (19) states that the household chooses to repay his debt whenever the expected discounted utility loss in the future, which arises due to exclusion form mortgage markets ensuing default, outweighs the current utility gain due to the forgiveness of mortgage debt when defaulting. If the opposite is true, the household decides to default.

The following proposition summarizes our findings about optimal household decisions:

Proposition 1. *Consumption expenditures on the standard good and housing services are proportional to each other, linear in current wealth, and increase in the individual portfolio return. Next-period wealth is linear in current wealth and increases in the individual portfolio return. Portfolio choices are independent of current portfolios and current wealth, but depend on next period's default decision rule. Default decisions are independent of* *wealth, but depend on portfolios.*

The proposition highlights the tractability of the model. Due to the separation of the consumption-savings decision from the portfolio choice and default decision, we just need to solve the latter problem numerically. In a nutshell, for given current portfolio θ and given mortgage price schedule (3), next period's optimal portfolio choice, θ'_{max}, and optimal default policy, d_{max}, are the solution to (18) and (19). Furthermore, the optimal portfolio choice of households in default $\theta'_{d,max}$ is independent of θ and p_m. For the consumption-savings problem, however, we use the analytical solution, that is, consumption policies (15) and (16) as well as savings policy (17).

2.2.2 Equilibrium

From now on, we focus on balanced growth path equilibria of the model economy. On a balanced growth path (BGP) all variables grow at constant rates. Suppose the economy grows at rate g which is endogenously determined in our model. Since the aggregate stock of housing is in fixed supply, on BGP the housing price $\tilde{p}_x$ grows at the growth rate of the economy.

To solve the model for a BGP equilibrium, it is useful to express the market clearing condition (5) in terms of stationary variables. For convenience, define $\tilde{w} = (1 + tr) \cdot (1 + r(\theta, d)) \cdot w$ as cash at hand, that is, wealth after all assets have paid off and after transfer payments. Let $\tilde{W} = E[\tilde{w}] = \sum_i E[\tilde{w}|j = i]\pi(i)$ denote total cash at hand,[7] then the share of cash at hand owned by type z is

$$\Omega^z = \frac{E[\tilde{w}|j = z]\pi(z)}{\tilde{W}} = \frac{E[\tilde{w}|j = z]\pi(z)}{\sum_i E[\tilde{w}|j = i]\pi(i)} \tag{20}$$

where $E[\tilde{w}|j = z]$ is the average cash-at-hand level of type z. For later reference, let $\Omega = \{\Omega^i\}_i$ denote the wealth distribution of households and note that Ω is a finite-dimensional object. The market clearing condition (5) can be written as

$$\begin{aligned} \tilde{K} &= \frac{\sum_i \theta_k^i \cdot \Omega^i}{\sum_i \theta_h^i \cdot \Omega^i} \\ p_x &= (1+g) \cdot \sum_i \theta_x^i \cdot \Omega^i \\ p_l &= \nu \frac{1-\beta}{\beta} \cdot (1+g) \end{aligned} \tag{21}$$

where the last line uses the consumption policy for housing services (16). Now, define a stationary recursive competitive equilibrium in the usual manner:

[7] Note that total cash at hand $\tilde{W}$ and aggregate wealth W are related by $W' = \frac{\beta}{1+\nu(1-\beta)} \cdot \tilde{W}$. Hence, on BGP total cash at hand and aggregate wealth grow at the same rate, g.

Stationary recursive competitive equilibrium. *For given government policy $\bar{\tau}$, a stationary recursive competitive equilibrium is a vector of prices $(p_x, p_l, p_m(\ell), \tilde{r}_k, \tilde{r}_h)$, household value functions V, V_d, household policy functions $c_1, c_2, w', \theta, d, c_{d1}, c_{d2}, w'_d, \theta_d$, and a stationary distribution of households Ω, such that*

1. *Utility maximization: the policy functions satisfy the household's problem (12) and (13), respectively;*
2. *Profit maximization: the aggregate capital-to-labor ratio $\tilde{K}$ satisfies the necessary and sufficient conditions for profit maximization (4);*
3. *Financial Intermediation: mortgage contracts are priced according to (3)*
4. *Market-clearing: condition (21) holds;*
5. *Policy: the government budget constraint (8) holds;*
6. *Consistency: the law of motion for aggregate wealth and the wealth distribution of households Ω are consistent with individual decisions.*

The stationary equilibrium is characterized in Appendix A.3 where the stationary wealth distribution Ω and the equilibrium growth rate are derived. It turns out that the growth rate is proportional to a weighted average of individual portfolio returns

$$1 + g = \frac{\beta(1 + tr)}{1 + \nu(1 - \beta)} \sum_i E[1 + r(\theta^i, s, j)] \cdot \Omega^i \tag{22}$$

Last but not least, for calibration purposes it is useful to compute the equilibrium rent-price ratio

$$\frac{p_l}{p_x} = \nu \frac{1 - \beta}{\beta} \frac{1}{\sum_i \theta_x^i \cdot \Omega^i} \tag{23}$$

which only depends on the housing portfolio shares θ_x, the wealth distribution, and model parameters.

Finding a stationary equilibrium means finding the three numbers $\tilde{K}, p_x$ and g solving (22) and (21), where the corresponding portfolio choice θ is the solution to the household decision problem and mortgage rates are determined by the zero profit condition for the banking sector.

Default policy. In stationary equilibrium, the optimal default policy can be characterized in more detail. Recall that the current default decision $d(\theta_x, \theta_m, s, j)$ has to satisfy condition (19) for given next-period optimal portfolio choice θ'_{max} as well as next-period optimal default policy d'_{max}. In a stationary equilibrium, both the portfolio choice and the default decision are time invariant, or $\theta'_{max} = \theta_{max}$ and $d'_{max} = d_{max}$. In other words, we are looking for a fix point of condition (19).

Suppose now that house price shocks ϵ have continuous support on $[\epsilon_{min}, \epsilon_{max}]$, but human capital shocks η are discrete. Then, the optimal default policy d_{max} is a cut-off rule. For every given portfolio state θ and human capital shock η_k with $k = 1, ..., K$, there exists a cut-off value ϵ_c for the house price shock such that if the realization of the shock is ϵ_c the household is indifferent between defaulting and repaying his debt. For better realizations of the house price shock, the household decides to repay; for worse, he defaults. Since the optimal portfolio choices depend only on the household type j, there are K default cut-off values for every type. In sum, the optimal default policy d_{max} is given by

$$d(\epsilon, \eta_k, j) = \begin{cases} 0 & if\ \epsilon \geq \epsilon_{ckj} \\ 1 & otherwise \end{cases} \tag{24}$$

where the cut-off values ϵ_{ckj} are determined by the requirement that condition (19) has to hold with equality. That is, continuous house price shocks yield the following indifference condition

$$\begin{aligned} & \beta \frac{1-\beta}{1+\nu} \sum_{j'} [\tilde{V}_0(j') - \tilde{V}_{0d}(j')] \pi(j'|j) \\ + & \quad \beta \sum_{j'} \sum_{k'} \int_{\epsilon_{ckj}}^{\epsilon_{max}} \ln(1 + r(\theta'_{max}(j), \epsilon', \eta'_k, j', 0))\, d\pi(\epsilon) \pi_k \pi(j'|j) \\ + & \quad \beta \sum_{j'} \sum_{k'} \int_{\epsilon_{min}}^{\epsilon_{ckj}} \ln(1 + r(\theta'_{max}(j), \epsilon', \eta'_k, j', 1))\, d\pi(\epsilon) \pi_k \pi(j'|j) \\ - & \quad \beta \sum_{j'} \sum_{k'} \ln(1 + r_d(\theta'_{d,max}(j), \eta'_k, j')) \pi_k \pi(j'|j)] \\ = & \quad \ln(1 + r(\theta, \epsilon_{ckj}, \eta_k, j, 1)) - \ln(1 + r(\theta, \epsilon_{ckj}, \eta_k, j, 0)) \\ \approx & \quad r(\theta, \epsilon_{ckj}, \eta_k, j, 1) - r(\theta, \epsilon_{ckj}, \eta_k, j, 0) \\ = & \quad -[\theta_m \frac{1}{p_{m,-1}} + \theta_x \frac{(1+\epsilon_{cj}) p_x + p_l}{p_{x,-1}}] \\ = & \quad -[m + ((1+\epsilon_{cj}) \tilde{p}_x + \tilde{p}_l) x]/w \end{aligned} \tag{25}$$

where the last three lines follow from a first-order Taylor approximation. Applying a first-order Taylor approximation, the gain from default is exactly the change in the portfolio return due to defaulting which is independent of the human capital shock η. Hence, the optimal default policy ϵ_{cj} does no longer depend on the labor shock.

For comparison, it is convenient to call the future utility loss due to exclusion – i.e.

the left hand side of the indifference condition – $\Upsilon(\theta^j, \epsilon_{cj})$ and rearrange terms

$$\epsilon_{cj} = \frac{-m}{\tilde{p}_x x} - \left(1 + \frac{\tilde{p}_l}{\tilde{p}_x}\right) - \frac{w}{\tilde{p}_x x} \cdot \Upsilon(\theta^j, \epsilon_{cj}) \tag{26}$$

The first term of the default cut-off is the amount of forgiven mortgage debt per dollar of the housing asset. The second term represents the loss of the house and its rent due to foreclosure. The third term captures the future utility loss due to default: As default triggers exclusion from mortgage markets for some time, the defaulter's portfolio choice is restricted to human and physical capital. Hence, the defaulter's portfolio will earn a lower return which decreases his future consumption. While $\Upsilon(\theta^j, \epsilon_{cj})$ is the future utility loss per unit of wealth, the third term in ϵ_{cj} is the future utility loss per dollar of the housing asset. Note that our default policy nests the cut-off rule of Jeske, Krueger, and Mitman (2013) if $p = 0$. That is, if there is no exclusion from mortgage markets, households will walk away from their mortgage debt as soon as the house is under water. However, if default is punished by an exclusion from mortgage markets in the future, the cut-off level will be lower. This means that households are willing to suffer some losses today in order to maintain the opportunity to borrow in the future.

The following proposition characterizes the stationary recursive competitive equilibrium of the model economy:

Proposition 2. *The value functions (14), consumption policies (15) and (16), savings policy (17), portfolio choices (18), default policy (24) with default cut-off values ϵ_{ckj} determined by indifference condition (25) for $\theta'_{max} = \theta_{max}$ and $d'_{max} = d_{max}$, an aggregate growth rate (22), a stationary wealth distribution Ω determined as fix point of (47), as well as prices given by (3), (4), and (21) comprise the stationary recursive competitive equilibrium of the model economy.*

3 Quantitative Analysis

In this section, we study the quantitative effects of the Taxpayer Relief Act of 1997 on the U.S. economy. In addition, we consider a hypothetical tax reform that repeals the preferential tax treatment of housing capital gains. To this end, we solve the model economy numerically for a partial equilibrium in the housing market and simulate these two reforms. First, we lay out our calibration strategy. Then, we describe the tax reform experiments in more detail and discuss our findings.

3.1 Calibration

The model economy's balanced growth path is calibrated to match various stylized facts of the U.S. economy before the Taxpayer Relief Act of 1997 came into effect, that is, the pre-TRA97 period. In the following, we lay out our calibration strategy. We begin with parameters that are directly related to our targets and can be set immediately. Then, the remaining parameters are calibrated jointly by matching a set of targets. All parameters are listed in Table 1.

Demographics. Let's begin with the demographic structure of the model population. We calibrate the ageing process to the following age groups: young (18-40 years), middle-aged (40-60 years), and old (60-85 years). Besides, the share of middle-aged households with high human capital return (type $m1$) $\pi(m1|m)$ is set to match an average loan-to-value ratio of 50% for the middle-aged group, as in U.S. data.[8] Next, the probabilities of being a first-time buyer b_y, b_m are set to match the home-ownership rates of young (37.9% for households younger than age 35) and middle-aged households (75.4% for age 45-54) in the 1995 Survey of Consumer Finances (Kennickell, Starr-McCluer, and Sunden, 1997). Finally, the probability of leaving default $1-p$ is calibrated to match an average duration of exclusion from mortgage markets of 10 years. This completes the calibration of exogenous type transition probabilities.

Taxation. Next, consider the tax system. The tax rate on capital gains from the sale of a home $\bar{\tau}$ is set to 25%. This matches the average marginal capital gains tax before TRA97 (Barro and Redlick, 2011). Furthermore, the probability of home sale ς is calibrated to match an mobility rate of 5%, as reported in the literature (Cunningham and Engelhardt, 2008; Shan, 2011). This implies an holding period of 20 years. Given that a capital gain from housing is only taxable if the house is downsized, the probability of a taxable home sale is 2.5% under this calibration.

Banks. Now we turn to the banking sector. There are two banking parameters to be calibrated: the cost of financial intermediation and the recovery rate at foreclosure. We follow Jeske, Krueger, and Mitman (2013) to calibrate the recovery rate at foreclosure γ to match an average loss in foreclosure $1-\gamma$ of 22%. Estimates for the cost of financial intermediation Δ vary considerably, ranging from 0.11% to 2.18% (Mehra, Piguillem, and Prescott, 2011; Mitman, 2012; Philippon, 2012). We choose an intermediate value of 1%.

Risk. Finally, the labor shock and the house price shock are to be calibrated. We choose the labor shock η to be normally distributed with zero mean and a standard deviation of 15% (see Krebs, 2003, and references therein). In our quantitative analysis, however, we consider a four-state approximation of the labor shock that is based on

[8] The 1995 Survey of Consumer Finances (Kennickell, Starr-McCluer, and Sunden, 1997) reports median values of asset holdings for families by age of head. We compute a loan-to-value ratios based on residential property of 50% for age groups both 45-54 and 55-64.

Gauss-Hermite quadrature. The individual house price shock ϵ is uniformly distributed with zero mean and a standard deviation of 20%.[9]

Having selected the parameters that are directly related to our targets, we now turn to the parameters which are calibrated jointly by solving the model and matching a set of model statistics with their data equivalents.

Preferences. First, consider the preference parameters. As usual, we calibrate the discount factor β to match the growth rate of the U.S. economy which is about 2% p.a. (Krebs, 2003). Next, we choose the utility weight of housing services consumption ν so that the model generates a rent-to-price ratio of 4.9% as calculated by Davis, Lehnert, and Martin (2008) for the aggregate stock of U.S. owner-occupied housing in 1997.

Finally, the disutility of being in default u_d can be used to calibrate the equilibrium foreclosure rate π_d as the indifference condition determining the default cutoff-level (25) suggests.[10] We follow Corbae and Quintin (2013) and target an aggregate annual foreclosure rate of 0.72%, computed as the population-weighted average of the default rates of all types holding mortgages. Our calibration implies a default rate of 1.75% for young households which is close to the U.S. foreclosure rate on subprime residential mortgages reported by the Federal Reserve Bank of Richmond (2011) for 1998.

Investment returns. Now, we turn to the calibration of the rental rates on physical and human capital. We aim at matching the portfolio choices by age-group, in particular the implied loan-to-value ratios. Our calibration strategy is as follows: first, consider households with high housing return, i.e. potential home-owners. For young households we target a loan-to-value ratio of 80% as computed from the 1995 Survey of Consumer Finances (Kennickell, Starr-McCluer, and Sunden, 1997) for households younger than age 35. In addition, we target a housing portfolio share of 22.5% which implies housing wealth of \$450'000 given total wealth of \$2'000'000. In sum, the portfolio target for young households is $\theta^y = (\theta^y_h, \theta^y_m, \theta^y_x, \theta^y_k) = (0.955, -0.18, 0.225, 0)$. To this end, we select the rental rates of human capital for young r^y_h and physical capital r_k which determines the mortgage rate appropriately.

The rental rate of human capital for middle-aged households with high human capital return r^{m1}_h is assumed to be the same as for young agents, while the corresponding rental rate for middle-aged with low human capital return r^{m2}_h is set to match a human capital portfolio share of 75% ($\theta^{m2}_h = 0.75$).

As we interpret old households as retired, their rental rate of human capital is set such

[9] There are several estimates of the cross-sectional house price volatility in the literature (e.g. Campbell and Cocco, 2014; Corbae and Quintin, 2013; Glaeser, Gyourko, and Saiz, 2008; Zhou and Haurin, 2010), ranging from 15% to 22%.

[10] In the quantitative analysis, we assume that the household suffers also in the period he actually defaults and, hence, enjoys just a fraction of the current utility gain due to default. We capture this idea by introducing the factor Γ to the right hand side of (25). We set $\Gamma = 0.25$.

Table 1: Calibration

Parameter	Symbol	Value	Target	Value	Source
			Preferences		
utility weight of housing service	ν	0.1369	rent-to-price ratio	4.9%	Davis, Lehnert, and Martin (2008)
discount factor	β	0.9629	consumption growth rate	2%	Krebs (2003)
utility cost of being in default	u_d	0.0272	aggregate foreclosure rate	0.72%	Corbae and Quintin (2013)
gain fraction	Γ	0.25			
			Technology		
depreciation rate	$\delta_h = \delta_h = \delta$	0.0713	mortgage-debt-to-GDP ratio	44%	NIPA, FOF
cost of financial intermediation	Δ	0.01		1%	literature: 0.11% - 2.18%
recovery rate at foreclosure	γ	0.78	average loss in foreclosure	22%	Jeske, Krueger, and Mitman (2013)
			Institutions		
housing tax rate	$\bar{\tau}$	0.25	average marginal capital gains tax	25%	Barro and Redlick (2011)
			Transition probabilities		
prob of leaving default	$1-p$	0.1	average duration of exclusion	10	
prob of home sale	ς	0.05	mobility rate	5%	Cunningham and Engelhardt (2008) Shan (2011)
prob of first-time buyer	b_y	0.0350	home-ownership rate of young	37.9%	SCF 1995, for age less 35
prob of first-time buyer	b_m	0.0792	home-ownership rate of middle-aged	75.4%	SCF 1995, for age 45-54
age transition probabilities	$\pi(j'\|j)$		average duration in group		age groups: 18-40; 40-60; 60-85
share of type m1	$\pi(m1\|m)$	0.5769	LTV of middle-aged	50%	SCF 1995, for age 45-54 & 55-64
			Shocks		
std. dev. of labor shock	std(η)	15%		15%	Krebs (2003)
std. dev. of house price shock	std(ϵ)	20%		20%	literature: 15% - 22%

that they do not invest in human capital, and, hence do not earn wage income. Besides, we assume old households are renters rather than home-owners. Consequently, they invest only in physical capital.[11]

Technology. Finally, we calibrate the depreciation rates as follows: we assume that the depreciation rates on physical and human capital are equal $\delta_k = \delta_h = \delta$. Then, we set δ such that the model economy matches the aggregate mortgage-debt-to-GDP ratio of 44% in 1997.[12]

3.2 Findings

The main quantitative experiment is to study the consequences of Taxpayer Relief Act of 1997 for the U.S. housing market. In addition, we simulate the effects of an hypothetical reform that would repeal the tax-breaks for owner-occupied housing and treat all capital gains in the same way.

3.2.1 The U.S. Tax Reform of 1997

In this section, we analyze the reform of housing-capital-gains taxation issued by the Taxpayer Relief Act of 1997. Before the 1997 reform capital gains from the sale of a primary residence were taxed as long as the taxpayer did not replace his residence by a more expensive one, rolling the capital gain over. Given a 20-years holding period of the home, the average taxable gain under our calibration amounts to ca. 50% which is taxed at the average marginal tax rate on capital gains of 25%. This implies an expected annual tax payment of 0.3% of individual housing wealth. Nowadays, capital gains from the sale of owner-occupied housing are de facto tax-exempt due to the TRA97.

The experiment. We mimic this reform by setting the tax rate for capital gains from housing $\bar{\tau}$ to zero. According to our calibration, the Taxpayer Relief Act of 1997 means, on average, a tax relief of 0.3% of individual housing wealth per year. We simulate this reform by computing the balanced growth path equilibrium of the post-reform model economy ($\bar{\tau} = 0$). This way, the computational experiment allows us to isolate the effects of the TRA97 from other factors that simultaneously impacted the U.S. economy during the post-TRA97 period. Comparing this simulated post-reform economy to the actual performance of the U.S. economy sheds light on the role the Taxpayer Relief Act of 1997 has played for the recent housing boom. In particular, this comparison allows us to quantify the fraction of the observed increase in U.S. house prices that can – according

[11] This assumption is necessary to get a plausible physical-capital-to-GDP ratio. Otherwise there would not be enough physical capital in the economy. The reason is that in our calibrated model economy home-owners do not hold physical capital and renters mainly invest into human capital.

[12] We compute the aggregate mortgage-debt-to-GDP ratio from NIPA and FOF data by dividing home mortgage debt of the household sector by GDP.

Table 2: TRA97 reform: portfolios by household type

	pre-TRA97				**post-TRA97, endo. default**			
	young	middle1	middle2	old	young	middle1	middle2	old
Human Capital	95.5	92.4	75.0	0.0	95.2	92.3	75.5	0.0
Mortgage	-18.0	-21.4	-5.4	0.0	-20.3	22.7	-6.6	0.0
Housing	22.5	29.0	30.4	0.0	25.1	30.4	31.1	0.0
Phys. Capital	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0
LTV Ratio	80.0	73.9	17.9	0.0	81.0	74.7	21.1	0.0
Default Rate	1.75	0.28	0.00	0.00	1.41	0.13	0.00	0.00

in per cent.
This table reports the portfolios of high-housing-return types, not in default. The corresponding portfolios for households in default consist of 100% human capital.

to the model – be attributed to the TRA97.

Effects on household behavior. Before discussing aggregate effects of the Taxpayer Relief Act, we inspect how individual households react to the tax-cut. We focus on household portfolios and their default decisions. Table 2 displays the results. As already mentioned, the TRA97 tax-cut implies an increase in the after-tax housing return by 31 basis points, holding all else equal. Consequently, investors adjust their portfolios. They take on additional mortgage debt in order to increase their housing portfolio share. Besides, young and middle-aged households with high human capital return (type $m1$) slightly shift resources from human capital into housing. As a result, their loan-to-value ratio increases. Middle-aged investors with low human capital return (type $m2$), in contrast, increase both their housing and their human capital share.

This suggests that the TRA97 reform has two counteracting effects: firstly, by increasing the after-tax return the tax-cut leads to a portfolio shift towards housing. Secondly, by abolishing the dependency of the housing tax on the human capital state the TRA97 reform induces more risk-taking. The reason is that before 1997 the roll-over rule implied that capital gains from housing were only taxed when the house was downsized. Downsizing, in turn, happens when negative human capital shocks hit the household. In this view, the pre-reform tax code had the opposite effects of an insurance. When abolishing this tax schedule, the middle-aged investor of type 2 reduces, consequently, his position in risk-free assets by increasing mortgage debt and shifts funds into human capital and housing which are risky. Young and middle-aged investors of type 1, however, do not have the opportunity to sell risk-free assets as neither they hold physical capital nor mortgage debt is save for them, given their positive default rate.

In fact, young and middle-aged investors of type 1 would have adjusted their portfolio in the same direction, if default rates had remained unchanged. However, default rates decreased by 34 and 15 basis points for young and middle-aged investors of type 1, respectively. Lower default rates, in turn, reduce the risk premium competitive banks charge to

Table 3: TRA97 reform: key statistics for the U.S. and model economies

	U.S. Economy		Model: TRA97 reform				
				exo. default		endo. default	
Statistic	1997	Δ_{1997}^{2007}	pre	post	Δ	post	Δ
Housing Tax Rate	25.0%[a]	-100%	25.0%[T]	0.0%	-100.0%	0.0%	-100.0%
House Price	100	+55%	0.1052	0.1113	+5.8%	0.1119	+6.4%
Rent-to-Price Ratio	4.9%[b]	-27%	4.9%[T]	4.63%	-5.5%	4.60%	-6.1%
Mortgage Debt/GDP	44.0%	+67%	44.0%[T]	49.4%	+12.3%	-49.0%	+11.3%
Housing Wealth/GDP	78.8%	+32%	79.1%	83.5%	+5.6%	84.1%	+6.3%
Loan-to-Value Ratio	55.8%	+26%	55.7%	59.2%	+6.4%	58.2%	+4.6%
Physical Capital/GDP			2.12	2.11	-0.3%	2.11	-0.3%
Growth Rate			2.00%[T]	1.98%	-1.0%	1.98%	-1.1%
Default Rate	0.72%[c]		0.72%[T]	0.72%	0.0%	0.55%	-23.8%

[a] Barro and Redlick (2011)
[b] Davis, Lehnert, and Martin (2008)
[c] Corbae and Quintin (2013)
[T] Target

cover their losses in foreclosure and, hence, mortgage rates. This means that households are willing to accept higher losses on their houses for a reduction in their mortgage rate. In contrast, if default rates had remained unchanged, mortgage rates would have increased due to the collateral channel. That is, higher loan-to-value ratios imply less collateral per unit of mortgage and, hence, higher losses in foreclosure. A decline in default rates, however, reduces mortgage rates and makes leverage less desirable. This way, endogenous mortgage default dampens the effects of the TRA97 reform on individual portfolios. Besides, for higher levered portfolios, the exclusion from mortgage markets ensuing default is more costly.

Aggregate effects. Now we turn to our evaluation of Taxpayer Relief Act of 1997. We analyze the effects of the tax reform on the U.S. macroeconomy and, in particular, the U.S. housing market. Table 3 reports the main results: we find that house prices increase by 6.4% due the TRA97 in our model, while the rent-to-price ratio declines by 30 basis points, or 6.1%. As a consequence, in equilibrium the expected after-tax housing return hardly changes. Furthermore, the mortgage-debt-to-GDP ratio increases by 11.3% and the aggregate loan-to-value ratio by 4.6%. Compared to the actual U.S. data for the period 1997 to 2007, our computational experiment accounts for more than one ninth of the observed increase in U.S. house prices of 55%. At the same time, almost a quarter of the observed decline in the aggregate rent-to-price ratio as well as a bit more than one sixth of the rise in both the aggregate loan-to-value ratio and mortgage-debt-to-GDP ratio can be attributed to the TRA97 reform. In a nutshell, our quantitative analysis suggests that Taxpayer Relief Act of 1997 made some important contributions to developments in the U.S. housing market during subsequent decade that culminated in a boom-bust-cycle.

Discussion. Microeconometric evaluations of the Taxpayer Relief Act of 1997 find that residential mobility rates increased by 19% to 31% among affected homeowners (Cunningham and Engelhardt, 2008; Shan, 2011). They argue that homeowners who wanted to buy a less expensive house felt "locked-in" before 1997 and the TRA97 enabled them to sell their homes without paying capital-gains taxes. Biehl and Hoyt (2014) provide evidence supporting this view: after 1997, home sellers were 6.6% less likely to move for a larger home and 6.2% more likely to move for a house that is cheaper to maintain. Finally, a recent study by Heuson and Painter (2014) does not only confirm the previous findings for affected homeowners. Rather, they find that housing turnover increased for all age groups and independently of whether homeowners traded up or down. Their time-series of aggregate housing turnover shows an increasing trend since the passage of the TRA97. By 2005, the peak, the turnover rate increased by almost two thirds, compared to 1997.

Clearly, our stylized way of modeling home sales abstracts from such considerations. Rather, by calibrating the sales probability to pre-TRA97 residential mobility rates we neglect locked-in households. Therefore, the current experiment may understate the share of households benefitting from the Taxpayer Relief Act.

3.2.2 Repeal of Housing Tax-breaks

In addition to the TRA97 reform, we study the effects of an hypothetical reform that would repeal the tax-breaks for capital gains from owner-occupied housing. Rather, these capital gains would be treated in exactly the same way as other capital gains. This counterfactual experiment serves as a natural benchmark case.

We implement this hypothetical reform by assuming that the tax function (6) is applied independently of the human capital shock, i.e. for every realization of η. While the tax rate $\bar{\tau}$ remains at 25% as in the pre-TRA97 economy, now every home sale would be taxable, even when the home is replaced by a more expensive one. Hence, the probability of a taxable home sale is now 5%, compared to 2.5% during the pre-reform period. This implies that the expected annual tax payment doubles to approximately 0.6% of individual housing wealth. Nevertheless, this hypothetical reform abolishes the anti-insurance character of the pre-1997 tax code, as the TRA97 did. However, by increasing the capital gains tax on housing, this reform would not nourish a housing boom. Rather, it could have mitigated the recent developments in the housing market.

Aggregate effects. On the aggregate level, such a repeal of the housing tax-breaks makes housing investments less attractive. Indeed, the proposed reform would reduce the expected after-tax return on housing by approximately 30 basis points, all else equal. As a result households reduce their housing portfolio shares, pay back some mortgage debt, and de-lever. Since housing demand goes down, the equilibrium house price falls by 4.1% so that the rent-to-price ratio increases by 21 basis points. Hence, in equilibrium

Table 4: Repeal of housing tax-breaks: key statistics for the U.S. and model economies

	U.S. Economy		**Model: repeal of housing tax-breaks**				
				exo. default		**endo. default**	
Statistic	1997	Δ_{1997}^{2007}	pre	post	Δ	post	Δ
Housing Tax Rate	25.0%[a]	-100%	25.0%[T]	25.0%	0.0%	25.0%	0.0%
House Price	100	+55%	0.1052	0.1006	-4.3%	0.1008	-4.1%
Rent-to-Price Ratio	4.9%[b]	-27%	4.9%[T]	5.12%	+4.5%	5.11%	4.3%
Mortgage Debt/GDP	44.0%	+67%	44.0%[T]	41.7%	-5.1%	-41.5%	-5.8%
Housing Wealth/GDP	78.8%	+32%	79.1%	75.6%	-4.4%	75.8%	-4.1%
Loan-to-Value Ratio	55.8%	+26%	55.7%	55.2%	-0.8%	54.7%	-1.7%
Physical Capital/GDP			2.12	2.12	0.0%	2.12	0.0%
Growth Rate			2.00%[T]	1.99%	-0.7%	1.99%	-0.7%
Default Rate	0.72%[c]		0.72%[T]	0.72%	0.0%	0.66%	-8.9%

[a] Barro and Redlick (2011)
[b] Davis, Lehnert, and Martin (2008)
[c] Corbae and Quintin (2013)
[T] Target

the expected after-tax housing return declines by only ca. 0.1%. Furthermore, aggregate housing wealth, relative to GDP, declines by 4.1%. The mortgage-debt-to-GDP ratio shrinks even stronger – to be precise: by 5.8% – so that the aggregate loan-to-value ratio declines by 1.7%. Default rates decline, too.

In sum, the computational experiment shows that a repeal of the housing tax-breaks has stabilizing effects on the economy by bringing down mortgage debt and leverage. In particular, the repeal of tax-breaks would have counteracted the house price boom during the 2000s. Altogether, implementing instead of the TRA97 a tax reform that treats capital gains on home sales as ordinary capital gains would have dampened the observed rise in house prices by about 20 percent.

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A Model Appendix

A.1 Demographic Structure

The population consists of three age groups $\{y, m, o\}$ and two housing-return groups $\{L, H\}$. Furthermore, for middle-aged households there are two human-capital-return groups $\{1, 2\}$. Combining the these groups with the solvency state, i.e. in default (d) / not in default (n), gives 12 types:[13]

- young, not in default, high housing return: ynH
- young, in default, high housing return: ydH
- young, not in default low housing return: ynL
- middle-aged 1, not in default, high housing return: m1dH
- middle-aged 1, in default, high housing return: m1dH
- middle-aged 1, not in default low housing return: m1nL
- middle-aged 2, not in default, high housing return: m2nH
- middle-aged 2, in default, high housing return: m2dH
- middle-aged 2, not in default low housing return: m2nL
- old, not in default, high housing return: onH
- old, in default, high housing return: odH
- old, not in default, low housing return: onL

Let Π^J denote the age transition matrix with typical transition probability $\pi_{a,b} = \pi(j' = b|j = a),\ a, b \in \{y, m1, m2, o\}$. Note that the transition from old to young is understood as death of old agents and birth of young agents. Given these age transitions, the exogenous probability of being a first-time home buyer b_j, the endogenous default probabilities π_j^d , and the exogenous probability of re-entering mortgage markets after default $(1 - p)$, type transitions are determined. The resulting type transition matrix is

$$\Pi^T = \begin{bmatrix} \Pi^T_{yy} & \Pi^T_{m1y} & \Pi^T_{m2y} & 0 \\ 0 & \Pi^T_{m1m1} & 0 & \Pi^T_{om1} \\ 0 & 0 & \Pi^T_{m2m2} & \Pi^T_{om2} \\ \Pi^T_{nb} & 0 & 0 & \Pi^T_{oo} \end{bmatrix} \tag{27}$$

with

$$\Pi^T_{yy} = \begin{bmatrix} (1-\pi^d_y)\pi(y|y) & \pi^d_y\pi(y|y) & 0 \\ (1-p)\pi(y|y) & p\pi(y|y) & 0 \\ b_y\pi(y|y) & 0 & (1-b_y)\pi(y|y) \end{bmatrix} \tag{28}$$

[13]Note that according to this type classification the groups ynH and m1nH consist of both agents that decide to pay off their mortgage debt and those that decide to default.

$$\Pi^T_{m1y} = \begin{bmatrix} (1-\pi^d_y)\pi(m1|y) & \pi^d_y\pi(m1|y) & 0 \\ (1-p)\pi(m1|y) & p\pi(m1|y) & 0 \\ b_y\pi(m1|y) & 0 & (1-b_y)\pi(m1|y) \end{bmatrix} \tag{29}$$

$$\Pi^T_{m2y} = \begin{bmatrix} (1-\pi^d_y)\pi(m2|y) & \pi^d_y\pi(m2|y) & 0 \\ (1-p)\pi(m2|y) & p\pi(m2|y) & 0 \\ b_y\pi(m2|y) & 0 & (1-b_y)\pi(m2|y) \end{bmatrix} \tag{30}$$

$$\Pi^T_{m1m1} = \begin{bmatrix} (1-\pi^d_{m1})\pi(m1|m1) & \pi^d_{m1}\pi(m1|m1) & 0 \\ (1-p)\pi(m1|m1) & p\pi(m1|m1) & 0 \\ b_m\pi(m1|m1) & 0 & (1-b_m)\pi(m1|m1) \end{bmatrix} \tag{31}$$

$$\Pi^T_{om1} = \begin{bmatrix} (1-\pi^d_{m1})\pi(o|m1) & \pi^d_{m1}\pi(m1|m1) & 0 \\ (1-p)\pi(o|m1) & p\pi(o|m1) & 0 \\ b_m\pi(o|m1) & 0 & (1-b_m)\pi(o|m1) \end{bmatrix} \tag{32}$$

$$\Pi^T_{m2m2} = \begin{bmatrix} \pi(m2|m2) & 0 & 0 \\ (1-p)\pi(m2|m2) & p\pi(m2|m2) & 0 \\ b_m\pi(m2|m2) & 0 & (1-b_m)\pi(m2|m2) \end{bmatrix} \tag{33}$$

$$\Pi^T_{om2} = \begin{bmatrix} \pi(o|m2) & 0 & 0 \\ (1-p)\pi(o|m2) & p\pi(o|m2) & 0 \\ b_m\pi(o|m2) & 0 & (1-b_m)\pi(o|m2) \end{bmatrix} \tag{34}$$

$$\Pi^T_{oo} = \begin{bmatrix} \pi(o|o) & 0 & 0 \\ (1-p)\pi(o|o) & p\pi(o|o) & 0 \\ b_o\pi(o|o) & 0 & (1-b_o)\pi(o|o) \end{bmatrix} \tag{35}$$

$$\Pi^T_{nb} = \begin{bmatrix} b_{nb}\pi(y|o) & 0 & (1-b_{nb})\pi(y|o) \\ b_{nb}\pi(y|o) & 0 & (1-b_{nb})\pi(y|o) \\ b_{nb}\pi(y|o) & 0 & (1-b_{nb})\pi(y|o) \end{bmatrix} \tag{36}$$

where b_{nb} is the probability that a newborn is of the high-housing-return type. However, in the following we assume that newborns do not inherit houses, i.e. $b_{nb} = 0$. In addition, old agents cannot be first-time buyers, i.e. $b_o = 0$.

Obviously, the demographic structure of the population evolves according to the law of motion

$$\pi_{t+1}^T = \Pi^T \cdot \pi_t^T \tag{37}$$

where π^T denotes the vector of population shares $\pi(j)$. The stationary type distribution is the fix point to this law of motion (37).

A.2 Solution to the Bellman equation

We solve the Bellman equations of the households decision problem (12) by the guess-and-verify method. Our guess is

$$\begin{aligned}
V(w,\theta,s,j,W) &= \tilde{V}_0(j) + \tilde{V}_1 \ln\left(1 + r(\theta,s,j,d(s,j))\right) + \tilde{V}_2 \ln w + \tilde{V}_3 \ln W \\
V_d(w,\theta_d,s,j,W) &= \tilde{V}_{0d}(j) + \tilde{V}_{1d} \ln\left(1 + r_d(\theta_d,s,j)\right) + \tilde{V}_{2d} \ln w + \tilde{V}_{3d} \ln W \\
c_1 &= \tilde{c}\left(1 + r(\theta,s,j,d(s,j))\right)(1+tr)w \\
c_{d1} &= \tilde{c}_d\left(1 + r_d(\theta_d,s,j)\right)(1+tr)w
\end{aligned} \tag{38}$$

Substituting this guess into the Bellman equation yields

$$\begin{aligned}
&\tilde{V}_0(j) + \tilde{V}_1 \ln\left(1 + r(\theta,s,j,d(s,j))\right) + \tilde{V}_2 \ln w + \tilde{V}_3 \ln W \;= \\
\max\;&\Big\{ \nu \ln(\nu/p_l) + \nu \ln W + \max_{\tilde{c}} \Big[(1+\nu)\ln\tilde{c} + \beta\tilde{V}_2 \ln(1-(1+\nu)\tilde{c})\Big] \\
&+ \beta \sum_{j'} \tilde{V}_0(j')\pi(j'|j) + \beta\tilde{V}_1 \max_{\theta'} \sum_{j'}\sum_{s'} \ln\left(1 + r(\theta',s',j',d(s',j'))\right)\pi(s')\pi(j'|j) \\
&+ (1+\nu+\beta\tilde{V}_2)\ln\left(1+r(\theta,s,j,0)\right) \;+\; (1+\nu+\beta\tilde{V}_2)\ln w \;+\; (1+\nu+\beta\tilde{V}_2)\ln(1+tr) \\
&+\beta\tilde{V}_3 \ln\left((1+g)W\right)\Big\}\;; \\
&\Big\{ \nu \ln(\nu/p_l) + \nu \ln W + \max_{\tilde{c}} \Big[(1+\nu)\ln\tilde{c} + \beta\tilde{V}_{2d} \ln(1-(1+\nu)\tilde{c})\Big] \\
&+\beta \sum_{j'} \tilde{V}_{0d}(j')\pi(j'|j) + \beta\tilde{V}_{1d} \max_{\theta'_d} \sum_{j'}\sum_{s'} \ln\left(1 + r_d(\theta'_d,s',j')\right)\pi(s')\pi(j'|j) \\
&+(1+\nu+\beta\tilde{V}_{2d})\ln\left(1+r(\theta,s,j,1)\right) \;+\; (1+\nu+\beta\tilde{V}_{2d})\ln w \;+\; (1+\nu+\beta\tilde{V}_{2d})\ln(1+tr) \\
&+\tilde{V}_{3d} \ln\left((1+g)W\right)\Big\}\Big\}
\end{aligned}$$

and

$$
\begin{aligned}
& \tilde{V}_{0d}(j) + \tilde{V}_{1d} \ln(1 + r_d(\theta, s, j)) + \tilde{V}_{2d} \ln w + \tilde{V}_{3d} \ln W \;= \\
& \nu \ln(\nu/p_l) + \nu \ln W \;-\; u_d \;+\; \max_{\tilde{c}_d} \left[(1+\nu)\ln \tilde{c}_d + \beta \left(p\tilde{V}_{2d} + (1-p)\tilde{V}_2\right) \ln(1-(1+\nu)\tilde{c}_d)\right] \\
+ \;\; & \beta p \sum_{j'} \tilde{V}_{0d}(j')\pi(j'|j) + \beta(1-p)\sum_{j'} \tilde{V}_0(j')\pi(j'|j) \\
+ \;\; & \beta \left(p\tilde{V}_{1d} + (1-p)\tilde{V}_1\right) \max_{\theta'_d} \sum_{j'} \sum_{s'} \ln(1 + r_d(\theta'_d, s', j'))\, \pi(s')\pi(j'|j) \\
+ \;\; & \left[1 + \nu + \beta\left(p\tilde{V}_{2d} + (1-p)\tilde{V}_2\right)\right] \ln(1 + r_d(\theta, s, j)) \\
+ \;\; & \left[1 + \nu + \beta\left(p\tilde{V}_{2d} + (1-p)\tilde{V}_2\right)\right] \ln w \;+\; \left[1 + \nu + \beta\left(p\tilde{V}_{2d} + (1-p)\tilde{V}_2\right)\right] \ln(1+tr) \\
+ \;\; & \beta \left(p\tilde{V}_{3d} + (1-p)\tilde{V}_3\right) \ln((1+g)W)
\end{aligned}
$$

The guess works for

$$
\begin{aligned}
\tilde{V}_1 = \tilde{V}_2 = \tilde{V}_{1d} = \tilde{V}_{2d} &= \frac{1+\nu}{1-\beta} \\
\tilde{V}_3 = \tilde{V}_{3d} &= \frac{\nu}{1-\beta} \\
\tilde{c} = \tilde{c}_d &= \frac{1-\beta}{1+\nu(1-\beta)}
\end{aligned}
$$

and $\tilde{V}_{0d}$ and $\tilde{V}_0$ given by

$$
\tilde{V}_0(j) \;=\; A + \beta \cdot \max \left\{ \sum_{j'} \tilde{V}_0(j')\pi(j'|j) + B(j) \;;\; \sum_{j'} \tilde{V}_{0d}(j')\pi(j'|j) + B_d(j) \right\} \tag{39}
$$

$$
\tilde{V}_{0d}(j) \;=\; A - u_d + \beta \left(p \sum_{j'} \tilde{V}_{0d}(j')\pi(j'|j) + (1-p) \sum_{j'} \tilde{V}_0(j')\pi(j'|j) + \frac{B_d(j)}{(1-\beta p)} \right) \tag{40}
$$

where

$$
\begin{aligned}
A &= \nu \ln(\nu/p_l) + \beta \ln(1+g) + (1+\nu)\ln(1-\beta) \\
&+ \frac{1+\nu}{1-\beta}\left[\beta \ln \beta - \ln(1+\nu(1-\beta)) + \ln(1+tr)\right] \\
B(j) &= \frac{1+\nu}{1-\beta} \sum_{j'} \sum_{s'} \ln(1 + r(\theta'_{max}(j), s', j', d(s', j'))) \, \pi(s')\pi(j'|j) \qquad (41) \\
B_d(j) &= \frac{1+\nu}{1-\beta} \sum_{j'} \sum_{s'} \ln\left(1 + r_d(\theta'_{max,d}(j), s', j')\right) \pi(s')\pi(j'|j)
\end{aligned}
$$

and θ'_{max} and $\theta'_{d,max}$ denote the optimal portfolio choices for next period and d the optimal default decision rule.

Note that $B(j) \geq B_d(j)$ as $r(\theta'_{max}(j), s', j', d(s', j') \geq r_d(\theta'_{max,d}(j), s', j')$ and suppose $\tilde{V}_0(j) \geq \tilde{V}_{0d}(j)$ for all j. Then $\tilde{V}_0(j) = A + \beta \cdot B(j)$. Denote $\tilde{\mathbf{V}}_0 = [\tilde{V}_0(y)\ \tilde{V}_0(m)\ \tilde{V}_0(o)]'$, $\tilde{\mathbf{V}}_{0d} = [\tilde{V}_{0d}(y)\ \tilde{V}_{0d}(m)\ \tilde{V}_{0d}(o)]'$, $\mathbf{B} = [B(y)\ B(m)\ B(o)]'$, $\mathbf{B_d} = [B_d(y)\ B_d(m)\ B_d(o)]'$, and Π the age-type transition matrix. Then equations (39) and (40) can be written in matrix notation as:

$$\tilde{\mathbf{V}}_0 = (I - \beta\Pi)^{-1}[A + \mathbf{B}] \tag{42}$$

$$\tilde{\mathbf{V}}_{0d} = (I - \beta p\Pi)^{-1}[A - u_d + \mathbf{B}_d + \beta(1-p)\tilde{\mathbf{V}}_0] \tag{43}$$

In other words, one has to solve a linear equation system to compute the constant terms of the value function $\tilde{V}_0(j), \tilde{V}_{0d}(j)$.

Default decision. Having substituted our solutions for the value function and the policy function into the Bellman equation that describes the decision problem of a household that is not in default (12), we can now solve the maximum operator for the default decision. Recall that the default policy function $d = d(\theta_x, \theta_m, s, j)$ maps the current state into a default decision $\{0, 1\}$ where 1 denotes default. Simplifying terms we get

$$\begin{aligned} & \frac{1+\nu}{1-\beta}\ln(1 + r(\theta, s, j, 0)) + \beta\sum_{j'}\tilde{V}_0(j')\pi(j'|j) \\ & + \frac{\beta(1+\nu)}{1-\beta}\sum_{j'}\sum_{s'}\ln(1 + r(\theta_{max}(j), s', j', d_{max}(s', j')))\pi(s')\pi(j'|j) \\ \geq\ & \frac{1+\nu}{1-\beta}\ln(1 + r(\theta, s, j, 1)) + \beta\sum_{j'}\tilde{V}_{0d}(j')\pi(j'|j) \\ & + \frac{\beta(1+\nu)}{1-\beta}\sum_{j'}\sum_{s'}\ln(1 + r_d(\theta_{d,max}(j), s', j'))\pi(s')\pi(j'|j) \end{aligned} \tag{44}$$

which has to hold for all states $(\theta_x, \theta_m, s, j)$ with $d(\theta_x, \theta_m, s, j) = 0$. And the reverse is true for all states $(\theta_x, \theta_m, s, j)$ with $d(\theta_x, \theta_m, s, j) = 1$. Rearranging terms, we get an easy-to-interpret condition that is stated in the main text, equation (19).

A.3 Characterization of the Stationary Equilibrium

The growth rate of the economy is determined as a weighted average of individual portfolio returns by the aggregation of individual wealth. First, recall that on BGP aggregate cash at hand $\tilde{W}$ and aggregate wealth W grow at the same rate g because of $W' = \frac{\beta}{1+\nu(1-\beta)} \cdot \tilde{W}$. Next, note that the law of motion for individual wealth (17), expressed in terms of cash at hand, reads as

$$\tilde{w}' = \frac{\beta}{1+\nu(1-\beta)} \cdot (1 + tr') \cdot (1 + r(\theta', d')) \cdot \tilde{w} \tag{45}$$

Finally, aggregation yields the growth rate

$$1 + g = \frac{\beta(1+tr)}{1+\nu(1-\beta)} \sum_i E[1 + r(\theta^i, s, j)] \cdot \Omega^i \tag{46}$$

Next, turn to the law of motion for the wealth distribution. The individual wealth share of type z, Ω^z, evolves according to

$$\begin{aligned} \Omega^{z\prime} &= \frac{E[\tilde{w}'|j' = z]\pi(z)}{\sum_i E[\tilde{w}'|j' = i]\pi(i)} \\ &= \frac{\sum_i E[(1+tr') \cdot (1 + r(\theta^{i\prime}, d')) \cdot \tilde{w}|j = i] \cdot \pi(z|i) \cdot \pi(i)}{\sum_m \sum_i E[(1+tr') \cdot (1 + r(\theta^{i\prime}, d')) \cdot \tilde{w}|j = i] \cdot \pi(m|i) \cdot \pi(i)} \\ &= \frac{\sum_i E[1 + r(\theta^{i\prime}, d')|j' = z] \cdot E[\tilde{w}|j = i] \cdot \pi(z|i) \cdot \pi(i)}{\sum_m \sum_i E[1 + r(\theta^{i\prime}, d')|j' = m] \cdot E[\tilde{w}|j = i] \cdot \pi(m|i) \cdot \pi(i)} \\ &= \frac{\sum_i E[1 + r(\theta^{i\prime}, d')|j' = z] \cdot \Omega^i \cdot \pi(z|i)}{\sum_m \sum_i E[1 + r(\theta^{i\prime}, d')|j' = m] \cdot \Omega^i \cdot \pi(m|i) \cdot} \end{aligned} \tag{47}$$

where the second line applies the equilibrium law of motion for individual cash at hand and the law of iterated expectations, the third line follows from the fact that portfolio choices are independent of wealth, and the last one simply uses the definition of Ω^z. The stationary wealth distribution Ω is determined as fix point of the law of motion (47).

B A brief History of the U.S. Law of Taxation

B.1 Personal Income Taxation

The U.S. federal government introduced personal income taxation in 1913. At that time the basic structure of the current federal income tax system was developed. Firstly, taxable income – the tax base – is defined, and secondly tax liabilities are computed by applying a tax schedule to taxable income (Slemrod and Bakija, 1999). The Internal Revenue Code of 1954, for example, defines taxable income as *"all income from whatever source derived"* minus allowable deductions minus personal exemptions and imposes a progressive tax schedule consisting of 24 brackets (for details see Sunley and Stotsky, 2005). In the following the major reforms since the 1970s are sketched:

- the Revenue Act of 1978 was a first step to simplify the income tax system: It reduced the number of tax brackets from 26 to 16, thereby lowering personal income taxes, and increased both the personal exemption and the standard deduction.
- the Economic Recovery Tax Act of 1981 gradually cut ordinary tax rates over 3 years and introduced inflation indexation of tax brackets in 1984.

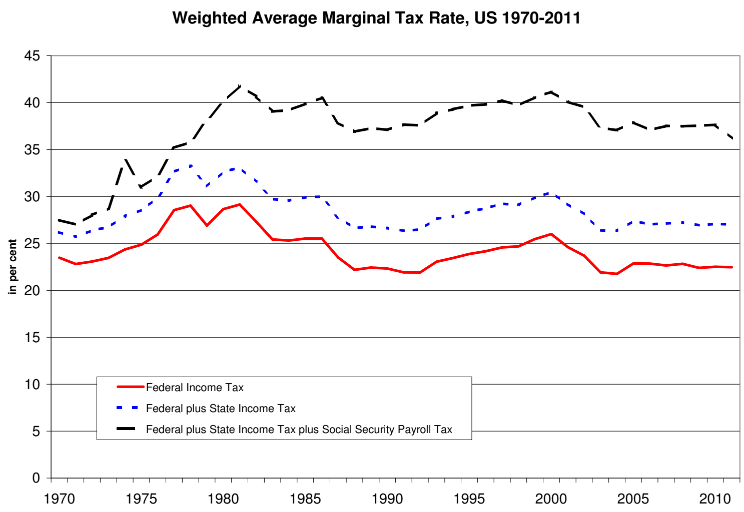

Figure 4: Average Marginal Income Tax Rate
SOURCE: Barro and Redlick (2011), updated data:
http://users.nber.org/~taxsim/marginal-tax-rates/index.html

- the Tax Reform Act of 1986 changed federal income taxation substantially: it broadened the tax base by cutting back preferences and exemptions, reduced the number of brackets to 5, and lowered ordinary tax rates.
- During the 1990s top marginal personal income tax rates were increased several times. However, the Taxpayer Relief Act of 1997 reduced capital gains tax rates and introduced a more favorable exemption for capital gains on home sales (see below).
- the Economic Growth and Tax Relief Reconciliation Act of 2001 created a new bottom rate of 10% and phased-in a lowering of the whole income tax schedule.

Figure 4 shows the development of the income tax burden, as measured by the source-of-income weighted average marginal tax rate (see Barro and Redlick, 2011), over time. The federal income tax time series reflects the Reagan tax cuts, the subsequent increase under Bush senior and Clinton, as well as Bush junior's tax relief. Detailed changes in the U.S. federal ordinary income tax schedule, in particular tax brackets and marginal rates, can be studied from Center for Federal Tax Policy (2011).

B.2 Capital Gains Taxation

U.S. federal income tax code distinguishes two types of realized capital gains depending on the holding period of the corresponding capital asset: short-term capital gains and long-term capital gains. While the former are subject to ordinary income taxation, long-term capital gains have generally been taxed at lower rates during the post-war period (Break, 1999).[14] The holding period required to classify as long-term was 6 month before 1977 and has been increased to 1 year for most of the following years.[15]

According to the Internal Revenue Code of 1954, only 50% of long-term capital gains where recognized for computing adjusted gross income (Esenwein, 2006; Office of the Secretary of the Treasury and Office of Tax Analysis, 1985). Hence, because of this exclusion, the effective tax rates applied to long-term capital gains were 50% of the ordinary rates. The 1978 Revenue Act lowered the capital gains tax by increasing the exclusion rate to 60%. However, the Tax Reform Act of 1986 repealed the exclusion of long-term capital gains and thereby increased capital gains rates (Auten, 2005; Esenwein, 2006). Till 1990 long-term capital gains were treated like ordinary income. Then the Revenue Reconciliation Act of 1990 established a maximum tax rate on long-term capital gains of 28% which was reduced to 20% by the Taxpayer Relief Act of 1997. Further reductions in the tax schedule were implemented by the Jobs and Growth Tax Relief Reconciliation Act of 2003 lowering the top marginal rate to 15%. Recent changes in the capital gains tax schedule are reported in Center for Federal Tax Policy (2010).

Figure 5 shows the statutory top marginal capital gains tax together with two series of weighted average marginal capital gains tax rates. Evidently, the link between statutory top marginal tax rates and average marginal taxes changed due to the Tax Reform Act of 1986: while during the 1970s statutory top rates were considerable higher than the marginal rate of an average taxpayer, the Reagan reforms led to a stronger comovement of top and average marginal rates. In particular, by reducing the number of tax brackets, the 1986 tax increase significantly affected the average taxpayer: the weighted average marginal capital gains tax was hiked up by almost 10 percentage points. However, recent tax reliefs more than reversed this hike by cutting top marginal rates.

B.3 Home Mortgage Interest Deduction

U.S. federal income tax has allowed for interest deductions since its creation. While in the beginning all interest paid within a year were deduced from income, the Tax Reform Act of 1986 limited interest deductions to "qualified residence interest" (Ventry, 2010). Interest qualifies for deduction if the corresponding loan is collateralized by a principal or secondary residence and used to buy, construct, or improve the residence (acquisition indebtedness). However, the total amount of deducible residence interest is limited to interests on the first $1 million (married filing) of acquisition indebtedness. In addition, regardless of the purpose of the mortgage, interests on home equity debt qualify for

[14] The only exception in the post-war period were the years 1987 to 1990 (Break, 1999).

[15] Esenwein (2006) reports a time-series with holdings period for long-term capital gains treatment.

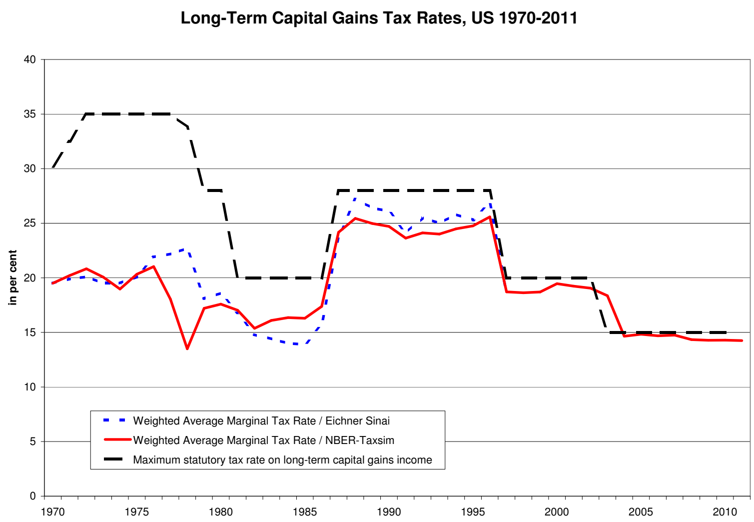

Figure 5: Federal Capital Gains Tax Rate
SOURCE: NBER Taxsim; Eichner and Sinai (2000); Esenwein (2006)

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deduction as long as home equity indebtedness does not exceed the market value of the residence minus acquisition indebtedness or $100'000 (married filing).

B.4 Capital Gains on Principal Residences

Under U.S. income tax code there is a special treatment of capital gains on the sale of a taxpayer's principal residence. The following special regulations deal with non-recognition of capital gains and tax exclusions. Capital gains on principal residences beyond these exclusions are subject to capital gain taxes.

Tax-free rollover of gains on home sales. Section 1034 of the Internal Revenue Code allowed taxpayers to defer recognition of a gain if the principal residence was replaced by another one of at least equal value. In this case capital gains were rolled over into the purchased residence. For eligibility, the replacement residence had to be bought and occupied within a year after the sale. The Tax Reduction Act of 1975 prolonged the replacement period to 18 month, and the Economic Recovery Act of 1981 increased the period to 2 years. This provision was valid from 1951 to 1997. (Office of the Secretary of the Treasury and Office of Tax Analysis, 1985; Ventry, 2010)

One-time exclusion of gains from home sales for elderly taxpayers. The Revenue Act of 1964 introduced a one-time exclusion of capital gains on the sale of principal residences up to $20'000. Taxpayers over the age of 65 were eligible for this exclusion if they had owned the house for at least 8 years and had lived in the house for at least 5 years before the sale. In 1976, the ceiling on the exclusion was increased to $35'000. The Revenue Act of 1978 shortened the occupation period to 3 out of the last 5

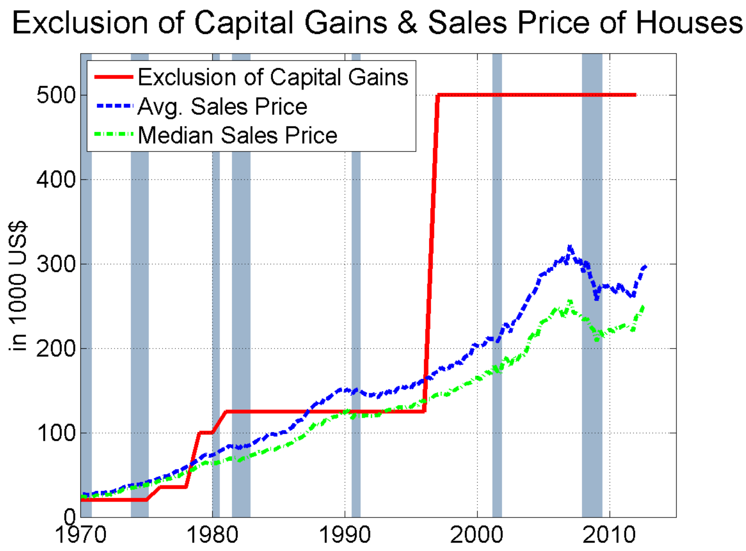

Figure 6: Exclusion of Capital Gains on the Sale of Principal Residences
NOTES: The shaded regions correspond to NBER-recessions.

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years. Besides, it reduced the age limit to 55 years and raised the exclusion to $100'000 (married filing). Finally, the Economic Recovery Tax Act of 1981 increased this allowance to $125'000 (married filing) (Auten, 2005; Newman and Reschovsky, 1987; Office of the Secretary of the Treasury and Office of Tax Analysis, 1985).

Taxpayer Relief Act of 1997. The Taxpayer Relief Act of 1997 replaced both the tax-free rollover and the one-time exclusion by a new exclusion of up to $500'000 (married filing) which can be claimed once every two years. Taxpayers qualify for this exclusion if they have owned and lived in the residence during 2 of the last 5 years prior to the sale. This exclusion of gain from sale of principal residence is codified in Section 121 of the Internal Revenue Code. (Auten, 2005; Office of the Secretary of the Treasury and Office of Tax Analysis, 1985; Ventry, 2010).

Figure 6 displays these exclusions of capital gains together with two time-series of house prices. As the sales price of a house constitutes an upper bound of the realized capital gain, we can infer from Figure 6 that these gains on the sale of a primary residence are effectively tax-free for the vast majority of households.[16]

[16]Data from FRED, for example, indicate that only 4 to 12 per cent of new houses sold in the U.S. in the years 2002 to 2012 were sold at prices exceeding $500'000. Shan (2011, p. 187) mentions that *"about 5% of homeowners in the 2007 SCF have more than $500 K housing capital gains. Among them, the median homeowner also faces a tax liability of around $30,000."*

C Mortgage default

A mortgage is considered to be in default when the borrower does not make his payments on the mortgage. Typically, mortgage documents define that default occurs if more than 30 days after the due date pass by. Then the lender is allowed to initiate foreclosure, i.e. the legal process by which the mortgage holder forces a sale of the property used as collateral. Usually banks begin the foreclosure procedure within the next two or three months. Moreover, they will also notify a credit agency of the mortgage default (Elias, 2011; Garriga and Schlagenhauf, 2009; Li and White, 2009).

C.1 Foreclosure

State legislations vary with respect to the details determining foreclosure. By and large, there are two types of procedures: judicial foreclosures and non-judicial foreclosures. In case of judicial foreclosure, the whole process is supervised by a court and the lender has to obtain a court order before auctioning the property. Non-judicial foreclosures or foreclosures by power of sale, in contrast, do not require judicial supervision. Instead mortgage lenders proceed according to the specifics set out by state law. In both cases, the mortgage holder will eventually obtain a legal title to the property and sell it. However, there is a substantial variation in the duration of the foreclosure procedure across states (Elias, 2011; Li and White, 2009).

The sales price after expenses is used to repay the mortgage debt. Often the revenues are insufficient to repay the mortgage completely. Whether the borrower still owes the difference between the principal and the sales revenue depends again on state law.[17] In some states the mortgage is non-recourse debt which means that the lender cannot sue the borrower to cover the losses evoked by foreclosure. Hence, the borrowers other assets are protected. In most states, however, mortgages are recourse debt so that the lender may obtain a deficiency judgment which obligates the borrower to repay the difference from his other assets.[18] In most judicial foreclosure states a deficiency judgment can be part of the foreclosure lawsuit while a few judicial foreclosure and all non-judicial foreclosure states require a separate lawsuit. In the latter states lenders have to incur substantially higher costs in pursuing a deficiency and, hence, won't often do so (Elias, 2011; Garriga and Schlagenhauf, 2009; Ghent and Kudlyak, 2011; Mitman, 2012).

If mortgage debt is (legally or de facto) non-recourse, borrowers have an incentive to default strategically. Strategic default means the borrower can afford to service his debt but decides to default because the home has turned into a lousy investment with its

[17] Many states limit deficiency to the difference between loan amount and fair market value.

[18] According to the classification of Ghent and Kudlyak (2011) in 41 U.S. states mortgages are recourse and in 11 states non-recourse debt.

current value falling below the mortgage debt. In this case the limitation of liability to the collateral allows the borrower to walk away from his mortgage debt by sacrificing his home while keeping his other assets (Elias, 2011; Lerner, 2010).

C.2 Future credit standing

Being a predictor of future credit risk, arrears and foreclosures have a negative impact on the borrower's credit score. According to the American Bankers Association the FICO score deteriorates by 100 to 400 points due to a foreclosure. Foreclosures remain on a credit report for at least seven years. However, scores typically recover after a couple of years given the borrower fulfills all his payment obligations (Lerner, 2010). The following rule of thumb characterizes lending customs before the recent crisis (Elias, 2011): it takes about two years after bankruptcy to rebuild credit scores in order to be able to buy a car and four to five for a house. Similarly, Lerner (2010) reports that it takes three to seven years to qualify for a new mortgage. Strategic defaulters, however, are nowadays penalized more severely: FannieMae and FreddieMac will effectively deny them a new mortgage for at least seven years after foreclosure due to new regulations they face (Elias, 2011; Lerner, 2010).

C.3 Tax issues

A short sale or foreclosure may incur capital gains tax liability. If the sales price is higher than the adjusted tax basis of the house, this difference qualifies as a capital gain which is taxed at the capital gains tax rate (Elias, 2011). For capital gains on principal residences the usual tax-breaks are available (see Appendix B.4).

At the same time an income tax liability may arise. Suppose the house is sold for less than the actual debt and the borrower's remaining debt is forgiven. Then, this deficiency is, in general, subject to income taxation. Since from the tax system's perspective the borrower receives a gift from the lender which amounts to the difference between principal and sales revenue. Hence, this amount counts as taxable income. However, since 2007 there is an exception to this rule: deficiencies on loans secured by and used to buy or improve the borrower's principal residence are exempt form income taxation. As a response to the current crisis, this Mortgage Forgiveness Debt Relief Act was intended to be a temporary exception but has been prolonged twice till end of 2013 (Elias, 2011; Garriga and Schlagenhauf, 2009).

D Data Sources

D.1 Federal Reserve Economic Data

The following time-series stem from the Federal Reserve Economic Data by the Federal Reserve Bank of St. Louis.

- Inflation rate: U.S. Department of Labor, Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items
- Consumer Price Index for All Urban Consumers: All items less shelter (CUUR0000SA0L2): U.S. Department of Labor, Bureau of Labor Statistics
- Gross Domestic Product: U.S. Department of Commerce, Bureau of Economic Analysis
- Home Mortgages (HMLBSHNO): Board of Governors of the Federal Reserve System, Z.1 Flow of Funds Accounts of the United States. Home mortgage debt is debt on owner-occupied homes, including home equity loans.
- Real estate of Households (incl. mobile homes and farm houses) at market value (REABSHNO): Board of Governors of the Federal Reserve System, Z.1 Flow of Funds Accounts of the United States
- Residential Structures of Households at Replacement-Cost Value (RCVSHNWBSHNO): Board of Governors of the Federal Reserve System, Z.1 Flow of Funds Accounts of the United States
- Delinquencies On Single-Family Residential Mortgages (DRSFRMACBN): Board of Governors of the Federal Reserve System, Charge-Off and Delinquency Rates on Loans and Leases at Commercial Banks
- Delinquency Rate On Loans Secured By Real Estate (DRSREACBN): Board of Governors of the Federal Reserve System, Charge-Off and Delinquency Rates on Loans and Leases at Commercial Banks

D.2 House Price Indices

- All-Transactions House Price Index for the United States (USSTHPI): Federal Housing Finance Agency, House Price Index (taken from FRED)

  The Federal Housing Finance Agency estimates a quarterly house price indexes for single-family detached properties using data on conventional conforming mortgage transactions obtained from Freddie Mac and Fannie Mae. Based on sales prices and appraisal data, the index measures average price changes in repeat sales or refinancings on the same properties.

- Average Sales Price of Houses Sold for the United States (ASPUS): U.S. Department of Commerce, Census Bureau, Quarterly New One-Family Home Sales by Price and Financing (taken from FRED)

- Median Sales Price of Houses Sold for the United States (MSPUS): U.S. Department of Commerce, Census Bureau, Quarterly New One-Family Home Sales by Price and Financing (taken from FRED)

- S&P Case-Shiller 20-City Home Price Index (SPCS20RSA): Standard and Poor's (taken from FRED)

  The S&P Case-Shiller 20-City Home Price Index tracks Single-Family housing in on 20 metro areas. Data are collected on transactions of all residential properties during the months in question. The composite index is a weighted average of the different regional indices which calculated as a three-month moving average from the collected data.

D.3 Rent-Price Ratio

Davis, Lehnert, and Martin (2008) compute a quarterly time-series of the ratio of imputed annual rents of homeowners to the value of owner-occupied housing in the U.S. To estimate the rent-price ratio, they use micro data from the Decennial Census of Housing surveys. In between these decennial surveys they interpolate rents and house prices employing the BLS's index for the rent of primary residence and Freddie Mac's repeat-sales house price index (CMHPI). These quarterly rent-price ratio data are regularly updated by the Lincoln Institute of Land Policy and published at `http://www.lincolninst.edu/subcenters/land-values/rent-price-ratio.asp`. For the period starting in 2000, the Lincoln Institute computes an alternative series of the rent-price ratio when house prices are based on the Case-Shiller-Weiss index.

D.4 Taxation

D.4.1 Ordinary income taxation

Barro and Redlick (2011) compile an annual time-series of average marginal income tax rates (AMTR) in the U.S. Their AMTR measure comprises of federal individual income taxes, state income taxes as well as the social security payroll tax. Recent data is mainly derived from the NBER TAXSIM program which depicts the U.S. federal and state income systems (for details see Feenberg and Coutts, 1993). The AMTR measure is intended to capture a concept of income that is close to labor income. Hence, Barro and Redlick (2011) calculate marginal tax rates for wages and related forms of income. Then, they compute the AMTR as the weighted mean of these marginal rates where the weight is the amount of income of various types reported on the filing. Daniel Feenberg of the NBER publishes updated AMTR data at `http://users.nber.org/~taxsim/barro-redlick/`

D.4.2 Long-term capital gains taxation

- Maximum statutory marginal tax rates for the U.S. are compiled in Esenwein (2006). The maximum statutory marginal capital gains tax rate is the marginal tax rate on the highest income bracket.
- Eichner and Sinai (2000) construct a time-series of the weighted average marginal capital gains tax rate for the period 1954 to 1997 following the methodology of the U.S. Congressional Budget Office.
- Average marginal long-term capital gains tax rates are taken from NBER's Average Marginal U.S. Income Tax Rates by Income Type table. They are dollar weighted average marginal tax rates derived from the NBER TAXSIM model (for details see `http://users.nber.org/~taxsim/marginal-tax-rates/index.html`).