Proposition 13: An Equilibrium Analysis*

Ayşe İmrohoroğlu‡ Kyle Matoba‡ Şelale Tuzel§

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Abstract

There are many federal, state, and local laws that distort housing decisions and prices. However, it is often difficult to tease out the quantitative impact of such policies. In this paper, we examine the implications of one of the most significant tax changes initiated by voters in the United States on house prices, housing turnover, and household welfare. In 1978 California passed Proposition 13, which lowered property tax rates and restricted future property tax increases. We find that, the introduction of Proposition 13 leads to a 15% increase in house prices and a 3.3% decrease in the moving rates. The elimination of Proposition 13, however, leads to modest changes in house prices and mobility but sizable welfare gains.

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†Department of Finance and Business Economics, Marshall School of Business, University of Southern California, Los Angeles, CA 90089-1427. E-mail: ayse@marshall.usc.edu

‡GSA Capital Partners. 5 Stratton Street. London W1J 8LA. Email: kyle.matoba@gsacapital.com.

§Department of Finance and Business Economics, Marshall School of Business, University of Southern California, Los Angeles, CA 90089-1427. E-mail: tuzel@marshall.usc.edu.
Introduction

Property taxes are the largest source of state and local tax revenues in the United States. Economists in general favor property taxes, arguing that they are less distortionary than other taxes. Yet, the last forty years have seen a dramatic restructuring of property taxes where voters in many states have passed measures that limit the ability of the government to raise revenues through property taxes. The first voter-approved state level restriction was enacted in 1978, where Californians passed Proposition 13. This resulted in two major changes, a decline in the average property tax rate, and a schedule that made tax rates depend on housing tenure.\footnote{We define housing tenure as the number of years since the house is purchased.} Since then, 19 other states have passed similar measures.

While Proposition 13 remains popular among voters, discussions about its impact and potential modifications to it continue. Despite the widely held belief that Proposition 13 reduces household mobility, the empirical literature has been unsuccessful in generating compelling estimates for such an effect. It has been similarly difficult to assess the potential impact of its elimination on the housing market. More importantly, the welfare implications of Proposition 13, which are expected to be quite heterogenous among a diverse set of agents composed of renters, home owners and various age groups, have been challenging to quantify. The objective of this paper is to construct a carefully calibrated dynamic general equilibrium model to assess the effects of Proposition 13 on housing allocations, prices, and welfare of households.

Our model economy consists of overlapping generations of individuals where working-age agents face an inverse U-shaped labor income profile that is subject to idiosyncratic shocks. Upon retirement, agents receive a certain income through Social Security. All agents face shocks that may force them to move out of their current homes. Households start life as renters and decide whether to rent or buy, the size of their house, and how much to spend on the consump-
tion of goods every period. They can borrow subject to collateral constraints or accumulate savings. Homeowners pay property taxes annually, and face transaction costs if they sell their homes. We show that the model is able to mimic some of the key features of the micro data, in particular homeownership and mobility over the life-cycle, and the relationship between the effective property tax rates and age as well as housing tenure in California.

We start by studying an economy without Proposition 13 where the property tax rate is set at 2.5% (roughly the average property tax rate in California in 1978, before Proposition 13), and the property taxes are calculated based on the current market value of the property. With the introduction of Proposition 13, the property tax rate is reduced to 1%, and property taxes are based on the value of the house at the time it was purchased (adjusted upwards at 2% per year). This second feature results in effective taxes that decline in housing tenure, and therefore by age, distorting housing choices over the life-cycle. In our benchmark calibration, we find that introducing Proposition 13 leads to a 15% increase in house prices which mainly reflects the present value of the decline in property tax payments and is consistent with the empirical estimates in Rosen (1982). More importantly, we find the lock-in effect of Proposition 13 to be small, especially in economies with high transaction costs and idiosyncratic move shocks. Transactions costs create a major deterrent against frequent moves, while the possibility of involuntary move shocks reduce the frequency of the planned moves by individuals. These findings help explain why it has been challenging to tease out the lock-in effect of Proposition 13 in empirical studies.\footnote{For example, Wasi and White (2005) find that, from 1970 to 2000, the average tenure length of owners in California increased by 6% relative to that of owners in comparison states due to Proposition 13. However, Stols, Childs, and Stevenson (2001) find smaller lock-in effects when they compare single family home sales records in California versus Illinois and Massachusetts. O’Sullivan, Sexton, and Sheffrin (1993) and Nagy (1997) also report a small impact of Proposition 13 on mobility. To precisely isolate the lock-in effect, Ferreira (2010) examines the behavior of 55-year-old homeowners who, due to some later propositions, were given the privilege to carry the Proposition 13 benefits with them if they purchased a house of equal or lesser value. He finds that this age group has a 30-38\% higher likelihood of moving compared to 54-year-olds who do not have the same privilege.}

We then proceed to the key goal of the paper where we examine the con-
sequences of eliminating Proposition 13 by removing the link between housing tenure and property taxes. In these experiments we keep the average tax revenues constant by reducing sales, income, or property tax rates. We find that the elimination of Proposition 13 would most likely have a small effect on house prices and mobility regardless of how revenue neutrality is achieved. This is due to our finding that the lock-in effect of Proposition 13 remains small in the face of transaction costs and move shocks. Consequently, as long as the property tax rate does not change significantly, which is the case in our revenue neutral experiments, elimination of Proposition 13 has only a small impact on house prices.

Despite its limited effect on the housing markets, we find that the steady state welfare gains from the reform can be quite large and stem mostly from the decline in the tax burden while young and borrowing constrained. However, the level of support for reform is usually low once transitions are taken into account. Renters, homeowners, and various age groups are impacted differently depending on how revenue neutrality is achieved. According to our findings, the case where revenue neutrality is accomplished by a reduction in the sales tax rate generates the highest level of support. Support levels decline further if property prices increase as a result of the reform, especially from the renters and the young individuals, who are the main groups to benefit from such reform.

Our overlapping generations framework with idiosyncratic shocks as well as differences in incomes of different generations creates a rich environment to tease out different aspects of Proposition 13. While the focus of this paper is on Proposition 13, our framework also contributes to the literature on equilibrium models of consumption and housing by constructing a rich and yet tractable model of housing, as in Corbae and Quintin (2015); Anagnostopoulous, Atesagaoglu, and Carceles-Poveda (2013); Favilukis, Ludvigson, and Van Nieuwerburgh (forthcoming); Sommer and Sullivan (2012); Chatterjee and Eyigungor (2011); Kiyotaki, Michaelides, and Nikolov (2011); Fisher and Gervais (2011); Chambers, Garriga, and Schlagenhauf (2009a,b); Diaz and Luengo-Prado (2008); Ortalo-Magné and Rady (2006); or Davis and Heath-
1 The Model

1.1 Demographics and Income

The economy is populated with overlapping generations of agents who have five life-stages.\(^3\) Every agent in life-stage \(a\) moves into the subsequent life-stage, \(a + 1\), with probability \(\pi_a\). With probability \(1 - \pi_a\), the agent spends another period in the same life-stage. The first four life-stages represent the working-age years while the last life-stage represents retirement years. During the first four stages, the individual labor income, \(y^a_t\), is given by \(\log(y^a_t) = \log(w^a) + e_t\). \(w^a\) is meant to capture a deterministic age-earnings profile during the life-cycle. \(e_t\) represents the stochastic shock to their income every period, given by: \(e_t = \Theta e_{t-1} + \varepsilon_t\). The disturbance term \(\varepsilon_t\), which is distributed normally with mean zero and variance \(\sigma^2\) and \(\Theta < 1\), captures the persistence of the stochastic component of labor income. In the last stage of life, individuals are retired and face a certain retirement income. During this stage of life, \(\pi_a\) represents the probability of death. When an agent dies, it is replaced by an agent in the first life-stage.

1.2 Housing

Our framework is similar to Gervais (2002) where individuals can either rent or own houses. Housing capital is discrete and households obtain housing services directly from their housing capital. A new cohort of individuals are born each period and start life with the smallest amount of housing that is available for rent. Individuals have access to the mortgage market but face a down payment requirement when purchasing a house. Homeowners face transaction costs when they sell their homes and must pay property taxes annually. Renters do not face property taxes directly. In addition to labor income shocks, individuals face exogenous (involuntary) move shocks that vary over the life

\(^3\)This feature is similar to Corbae and Quintin (2015) where households go through four life-stages and to Castaneda, Díaz-Gimenez, and Ríos-Rull (2003) where households go through two life-stages.
cycle. Similar to Cocco (2004), these shocks are meant to capture the other reasons for households to move, such as family-related shocks, health shocks, changes in employment, or location preferences. Each period, after observing their labor income and move shocks, households make their consumption decisions along with their housing and mortgage arrangements for the next period.

There are financial institutions in the background who pool individuals’ deposits, provide loans to homeowners, and hold residential rental capital. All rental housing units are owned by these financial institutions and turned into housing services via a linear technology. In this framework, the housing stock corresponds to the owner-occupied housing plus the housing stock held by financial institutions. We take the total housing stock, $H$, as fixed.\footnote{This assumption seems reasonable since our main focus is on the transitions after a change in policy. However, even in the long run in California, the per capita supply of single family homes has been relatively stable since the 1970s. We compute per capita housing supply in California by using data from the Census of Housing, which is available every 10 years, and data on housing permits, which is available annually. Between 1975 and 2014, the average per capita supply of single family homes has been between 0.36 and 0.39. Nevertheless, we also present results where housing supply is assumed to be fully flexible.}

We model California as a small open economy and take the interest rate on deposits and mortgages given by the United States market. We assume that agents can either be savers, earning an interest rate of $r^d$ or borrowers in the mortgage market facing a mortgage interest rate of $r^m$. We do not allow uncollateralized borrowing.

### 1.3 Individual’s Problem

Individuals derive utility from a composite of consumption goods and housing services. Let $h_t$ denote the quantity of housing services consumed by an agent at date $t$ and $h$ indicate the set of house sizes available for renters. $h_t \in h$ indicates an agent who rents, and $h_t \notin h$ indicates an agent who is a homeowner. Current homeowners are responsible for paying property taxes and face a transaction cost if they sell their house. We assume that at each period $t$, individuals may receive an idiosyncratic shock that will force them to move...
to a new house. Let \( v_t = 1 \) denote the state with the move shock and \( v_t = 0 \) denote the state without the shock. For a homeowner, the move shock results in the sale of the current house and triggers the transaction cost of selling. An individual who is a renter may be forced to move as well (where they might choose to move to a rental or an owner-occupied house) but does not incur a transaction cost. Transaction costs, \( F(h_t, h_{t+1}, v_t) \) are given by:

\[
F(h_t, h_{t+1}, v_t) = \begin{cases} 
\varphi p_t h_t & \text{if } h_t \notin \mathcal{h} \text{ and } v_t = 1 \\
\varphi p_t h_t & \text{if } h_t \notin \mathcal{h} \text{ and } h_{t+1} \neq h_t \text{ and } v_t = 0 \\
0 & \text{otherwise}
\end{cases}
\]

(1)

where \( p_t \) is the price of a unit of housing, and \( \varphi \) represents the proportion of the housing value paid as transaction costs such as fees paid to real estate agents. Homeowners who receive a move shock \((v_t = 1)\) automatically face transaction costs even if they move to an identical house. In the absence of a move shock, homeowners who move to a home of a different size (rental or owner-occupied) face transaction costs. All renters, including those who buy homes \((h_t \in \mathcal{h} \text{ and } h_{t+1} \notin \mathcal{h})\) or homeowners who remain in the same home \((h_t \notin \mathcal{h} \text{ and } h_{t+1} = h_t \text{ and } v_t = 0)\) do not pay the transaction cost.

Property taxes are paid by current homeowners \((h_t \notin \mathcal{h})\). In the absence of Proposition 13, property taxes are equal to the property tax rate, \( \tau_t^p \), times the value of the house, \( p_t h_t \). With Proposition 13, the value of the house for tax purposes, \( B_t \), depends on whether or not there has been a change in ownership, and is given by:

\[
B_t = \begin{cases} 
(1 + g)B_{t-1} & \text{if } h_t = h_{t-1} \text{ and } v_t = 0 \\
p_t h_t & \text{otherwise}
\end{cases}
\]

(2)

For homeowners who stay in the same house, the value of the house for tax purposes grows by \( g \). Finally, total property taxes paid is given by: \( T_t^p(h_t) = \tau_t^p B_t \).

Homeowners are allowed to borrow against the value of the house (mortgage
subject to a loan-to-value constraint $\eta$, given by:

$$m_{t+1} \leq \eta p_t h_{t+1} \quad \text{if} \ h_{t+1} \notin \mathcal{h}.$$  

(3)

We do not allow homeowners to default on their mortgages. Renters ($h_{t+1} \in \mathcal{h}$) do not have access to the mortgage market and are only allowed to save. A negative mortgage represents savings with a deposit rate of $r^d$.

$$r = \begin{cases} 
    r^m & \text{if} \ m_{t+1} > 0 \\
    r^d & \text{if} \ m_{t+1} < 0.
\end{cases}$$  

(4)

Similar to Castaneda et al. (2003) and Chambers et al. (2009b), we implement progressive income taxes to mimic the actual state and federal income tax code. We use the tax function estimated in Gouveia and Strauss (1994), which has the functional form given by:

$$T^i_t(\tilde{y}) = \tau_{\eta_0} \left[ \tilde{y} - \left( \tilde{y}^{\tau_{\eta_1} + \tau_{\eta_2}} \right)^{\frac{1}{\tau_{\eta_1}}} \right],$$  

(5)

where $\tilde{y}$ is taxable income, and $(\tau_{\eta_0}, \tau_{\eta_1}, \tau_{\eta_2})$ are policy parameters on income taxes. We assume that the interest paid on mortgages ($r m_t$) and property taxes paid ($T^p_t$) are tax deductible while interest on savings is taxable. Thus, taxable income of an individual before retirement is given by:

$$\tilde{y} = \max(0, [y^a_t - r m_t - T^p_t]).$$  

(6)

Social Security income of retired agents is not subject to the income tax. However, the property taxes they pay are still tax deductible from their interest income. Thus, for $a = 5$, taxable income is equal to

$$\tilde{y} = \max(0, -r m_t - T^p_t).$$  

(7)

\footnote{In the presence of income and move shocks, accidental defaults (or negative consumption) can be an issue. We confirmed that in our simulations agents always stay away from choices that could make accidental default a possibility.}
In case of the death of an agent, which occurs after the housing and saving decisions are made, the financial institution sells the house and distributes the net assets of all the deceased (accidental bequests) to the agents alive in the next period in a way proportional to their incomes. We denote this inheritance by $q_t$.\footnote{This redistribution scheme preserves the age-endowment profile (income and bequest). Distributing the accidental bequests equally to all agents generates qualitatively similar results.} Homes depreciate at the rate $\delta$, and homeowners must pay this fraction of the value of their homes, conceptually maintenance costs, in order to continue living in their home.

An agent’s budget constraint is a function of the current and future homeownership status. A homeowner who continues to be a homeowner (if $h_t \notin \mathbb{h}$ and $h_{t+1} \notin \mathbb{h}$) faces the following budget constrain:

\[
    c_t(1 + \tau_t^s) = y_t^a(1 + q_t) + p_t((1 - \delta)h_t - h_{t+1}) + (m_{t+1} - (1 + r)m_t) - T_t^i - T_t^p - F_t. 
\]  

(8)

where $c_t$ represents the non-housing consumption of an agent at time $t$. The agent pays property taxes $T_t^p$, and if they move, the transaction cost $F_t$. A homeowner who decides to rent in the next period (if $h_t \notin \mathbb{h}$ and $h_{t+1} \in \mathbb{h}$) is responsible for current property taxes and the transaction cost of selling the house. However, instead of paying for a new house, the agent pays rent, $rent_t$:

\[
    c_t(1 + \tau_t^s) = y_t^a(1 + q_t) + p_t((1 - \delta)h_t - rent_t h_{t+1}) + (m_{t+1} - (1 + r)m_t) - T_t^i - T_t^p - F_t. 
\]  

(9)

A renter who decides to buy a house (if $h_t \in \mathbb{h}$ and $h_{t+1} \notin \mathbb{h}$) is not responsible for property taxes or the transaction cost but pays for the new house:

\[
    c_t(1 + \tau_t^s) = y_t^a(1 + q_t) - p_t h_{t+1} + (m_{t+1} - (1 + r)m_t) - T_t^i. 
\]  

(10)
A renter who continues to rent \((h_t \in h \text{ and } h_{t+1} \in h)\) is also not responsible for property taxes or the transaction cost:

\[
ct (1 + \tau_t) = c_t h_{t+1} + (m_{t+1} - (1 + r)m_t) - T_t. \tag{11}
\]

The rental rate is determined by the competitive financial institutions such that it covers the depreciation expenditures, property taxes, and the mortgage interest payments, namely:\(^7\)

\[
rent_t = (r^m + \delta + \tau_t^p)p_t. \tag{12}
\]

1.4 Government

We assume that the state government abides by a balanced budget and finances its government expenditures, \(G_t\), with tax revenues collected through sales, property, and income taxes.

2 Equilibrium

Individuals at time \(t\) are heterogeneous with respect to life-stages \(a_t\), assets (mortgage) \(m_t\), housing \(h_t\), employment state \(e_t\), the move shocks they receive, \(v_t\), and the value of their house for tax purposes \(B_t\). Let \(\Gamma(e, e')\) be the transition matrix for labor income, \(\Pi(a, a')\) be the transition function for life-stages and \(\Omega_t\) represent the state \((a, m, h, e, v, B)\) faced by an agent at time \(t\). Let \(\Lambda^a(v')\) be the age-dependent probability for the move shock and \(V_t(\Omega)\) be the (maximized) value of the objective function at state \(\Omega_t\). The dynamic programming problem for the agent is given by:

\[
V_t(\Omega) = \max_{c, h', m'} u(c, h) + \beta \sum_{a'} \sum_{e'} \sum_{v'} \Pi(a, a') \Gamma(e, e') \Lambda^a(v') V_{t+1}(\Omega') \tag{13}
\]

\(^7\)See Gervais (2002) and Silos (2007) for derivations of the rental rate in similar environments.
subject to the constraints (1) - (12).

Given a sequence of government policy \( \{\tau_{\eta_0}, \tau_{\eta_1}, \tau_{\eta_2}, \tau^p_t, \tau^m_t\}_{t=1}^{\infty} \) and mortgage and deposit rates \( \{r^m_t, r^d_t\}_{t=1}^{\infty} \), a competitive equilibrium is a sequence of value functions \( V_t(\Omega) \), individual decision rules for consumption of goods, housing, and mortgage holdings, a measure of agent types \( \lambda_t(\Omega) \) and a price of housing \( p_t \), such that, for all \( t \):

1. Given the house price, the mortgage and deposit interest rates and the government policy, the individual decision rules solve the individual’s dynamic programming problem.

2. \( p_t \) clears the housing market, \( \sum_{\Omega} \lambda_t(\Omega) h_t(\Omega) = \Pi \), where \( h_t(\Omega) \) is the optimal housing allocation resulting from the dynamic programming problem of the household.

3. Accidental bequests are given by:

\[
q_t = \frac{\pi_5 \sum_{m, h, e, v; a = 5} \lambda_t(\Omega) [(1 - \delta)(p_t(\Omega) h_t(\Omega)) - (1 + r)(m_t(\Omega))]}{\sum_{\Omega} \lambda_t(\Omega) y^a_t}.
\]

Deaths occur (with probability \( \pi_5 \)) after agents of generation five have made their homeownership, mortgage, and savings decisions.

3 Calibration

We mostly use post Proposition 13 data for California to calibrate the initial steady state of the benchmark economy.\(^8\) For the aggregate statistics where there is no state level data, we use national level data (USA). We would like to generate a model economy that can match some of the key moments in the data, for example, the homeownership rate in California and the effective property tax rates over the life-cycle. We have, however, no free parameters\(^8\) Excluding data from the Great Recession in our calibration of the steady state does not change our results in any significant way.
to help us replicate the data fully. Consequently, we pay close attention to modeling essential features of the economy properly.

In the benchmark economy agents live through five life-stages. They work during the first four life-stages, on average representing ages 21-62, and are retired in the last life-stage representing ages 63-75. They face a constant probability $\pi_a$ of moving from life-stage $a$ to the next life-stage $a + 1$. We set $\pi_a$ so that agents, on average, spend ten and a half years in the first four stages of life, and thirteen in the last. This implies $\pi_a = 0.095$ for the first four life-stages. In the last life-stage, $\pi_a = 0.077$ represents the probability of death. The transition function $\Pi(a, a')$ for life-stages is given in the Appendix. This calibration results in an average life expectancy of 75 years, an average retirement age of 62.9

Next, we make sure that the labor income process used in the model is capable of generating the earning profile of agents in the data. We assume that the individual labor income during the working years (first four life-stages), $y^a_t$, is given by: $\log(y^a_t) = \log(w^a) + \epsilon_t$, where $w^a$ is calibrated to match the earnings profile of the agents with median lifetime earnings, computed by Guvenen et al. (2015), and takes the values (0.6, 0.9, 1.25, 1.60) for life-stages 1-4, respectively. $\epsilon_t$ represents the idiosyncratic component of labor income ($\epsilon_t = \Theta \epsilon_{t-1} + \epsilon_t$) and is calibrated using the estimates in Storesletten et al. (2004) with $\Theta = 0.95$ and $\sigma^2_\epsilon = 0.01$. We approximate this income process with a four-state Markov chain using the methodology presented in Adda and Cooper (2003). The discretized values for $\epsilon_t$ are: $(-0.41, -0.10, 0.10, 0.41)$ and the transition matrix is given in the Appendix.

During retirement, agents receive 40% of the average employed earnings.11

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9According to Center for Health Statistics (2004), the life expectancy at birth in California was 74.8 years between 1979-1981 and 80.2 years in 2004. In addition, according to Gendell (2001), the average retirement age in the U.S. was between 61.4 and 63 from 1975 to 2000. Our calibration yields values within the range of these observations.

10Guvenen et al. (2015) document that the median worker experiences much lower earnings growth over the life-cycle than the mean earnings growth computed from the entire sample. We target the earnings profile for the median earners for ages 25-60, such that the age-income profile for the median earners in the model mimics its counterpart in the data. See the online appendix for more details.

Note that in this framework, life-stage captures the earning capabilities of agents and not their actual age. Therefore, some agents may end up spending more or less than the average years in a given earnings stage, leading to, for example, some agents being “poor” for a long time. This feature of the model generates an increase in the dispersion of earnings by age that is present in the data but is difficult to generate in typical overlapping generations models.\textsuperscript{12}

We calibrate the income tax function given in equation 5 to the federal and state (California) personal income taxes. Similar to the federal income tax code, California has progressive income taxes. We assume that state and federal income taxes have the same level of progressivity.\textsuperscript{13} Of the three tax policy parameters ($\tau_{\eta_0}, \tau_{\eta_1}, \tau_{\eta_2}$), $\tau_{\eta_1}$ determines the progressivity of the taxes. Gouveia and Strauss (1994) estimate the value of $\tau_{\eta_1}$ as 0.768 and $\tau_{\eta_0}$ (for the federal income taxes) as 0.258. Since our tax function includes both state and federal income taxes, we set $\tau_{\eta_0}$, which scales the level of the taxes linearly, to 0.312 to account for both taxes.\textsuperscript{14} The last policy parameter, $\tau_{\eta_2}$ is not unit-independent and has to be calibrated. Similar to Castaneda et al. (2003), we choose the value of $\tau_{\eta_2}$ so that the federal tax rate levied on median household income in our benchmark model economy is the same as the effective federal tax rate on median household income in the U.S. economy. This results in $\tau_{\eta_2} = 1.5$.\textsuperscript{15}

The sales tax rate, $\tau^s$, and the property tax rate, $\tau^p$, are set to 10% and 1%, respectively. The resulting average tax revenues to income (and average government expenditures to income) is 25%. In our simulations, we investigate the consequences of changing each one of these tax rates ($\tau^s, \tau^p, \tau_{\eta_0}$) separately.

\textsuperscript{12}In our model, the variance of log income over ages increases from 9% at age 21 to 40% at the age of 60. Heathcote, Perri, and Violante (2010) report a similar increase in the variance of log wages using several different controls and data sets (their figures 14 & 15).

\textsuperscript{13}While it is more realistic and desirable to introduce progressive taxes, we obtain quantitatively similar results with flat taxes as well.

\textsuperscript{14}Using data from the Tax Policy Center and the IRS, we find that California personal income tax collections were 20.9% of federal personal income tax collections from Californians between 2007 and 2011. Therefore, we increase the estimate in Gouveia and Strauss (1994) by 20.9% and set $\tau_{\eta_0}$ equal to 0.312.

\textsuperscript{15}Based on data from the Tax Policy Center, the effective federal rate for the median household is 16.9% over the 1979-2001 period.
in order to conduct revenue-neutral experiments.

We set the housing grid based on data on the square footage of houses for homeowners and renters from the U.S. Census Bureau, American Housing Survey 2013. We normalize the average home size to 2 and let the agents choose from two different rental sizes (1 and 1.5) and four different sized owner-occupied units (1.75, 2.25, 3, and 4.5). The size of the rental units correspond to 33rd and 66th percentile of the size distribution of rentals, while the size of the owner-occupied units correspond to 33rd, 50th, 75th, and 95th percentiles of owner-occupied units in the data. The time period is selected to be a year. The subjective time discount factor, $\beta$, is assumed to be 0.96, which implies an annual subjective time discount rate of 4.2 percent. The per period utility function is given by: $U(c_t, h_t) = \frac{c_t^{1-\sigma}}{1-\sigma}$ where $\bar{c}_t = [c_t^{\chi} h_t^{1-\chi}]$. The relative weight of consumption in the utility function, $\chi$, is set so that the share of non-housing consumption is approximately equal to 0.67 as in California data. The risk aversion parameter in the utility function impacts the saving behavior of the households. We set this equal to 5 in our benchmark case as it helps the model match net financial wealth to income data better than lower values for this parameter that are more typical in the macro literature. In Section 5, we check the sensitivity of our results for the case where the risk aversion parameter is set to 2.

In the data, there are significant differences in the probability of moving across age groups. We calibrate the exogenous move shocks for agents in

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16 Average home size is 1,739 square feet in the data. See Section 7.2 for more details.
17 With these grid choices, model generated distribution of housing allocations is roughly in line with their data counterparts. Moreover, our results are robust to several different grid choices, including having a rental choice that is larger than the smallest owner occupied unit.
18 The share of non-housing consumption to income is calculated from the BEA data. We calculate non-housing consumption as the personal consumption expenditures net of housing, furnishing, and utilities. Income is the sum of compensation of employees, proprietor’s income, and personal current transfers.
19 We assume that move shocks are independent of idiosyncratic income shocks. In reality, some people may need to move across county lines to take advantage of a wage opportunity. However, inter-county mobility make up a small share of all moves (3.8% between 2012 and 2013), and job-related moves make up roughly one third of these moves. (Estimates are based on the Census Bureau report, Reason for Moving: 2012 to 2013.) Chen and
each life-stage such that the resulting moving rates by age, which are the results of both exogenous and endogenous moves, mimic their counterparts in the data. These exogenous move probabilities (for $v' = 1$) are given by $\Lambda = [0.30, 0, 0.02, 0.06, 0.03]$ for life-stages 1-5, respectively.

We treat California as a small open economy and set the mortgage interest rate and the rate of return on deposits as constant at 4.2% and 1.7%, respectively. The transaction cost of selling a house is assumed to be 6%, which, according to Gruber and Martin (2003), is on the conservative side of the estimates. However, given the changes in this industry with online brokers and agents, we also investigate the sensitivity of our results to lower transaction costs. We set the maximum loan-to-value (LTV), $\eta$, at 80%.

Table 1

Rosenthal (2008) investigate individual migration decisions using IPUMS data. Consistent with the Census statistics, they find that among movers, an important reason for moving is the availability of local amenities (e.g., climate, temperature, non-metropolitan areas, etc.), which is not directly related to wages. In addition, Kennan and Walker (2011) develop an econometric model of optimal migration, and find that, while migration decisions are influenced by income prospects, many of the moves are motivated by something other than income gains.

Mobility data are for California, from Integrated Public Use Microdata Series (IPUMS) and covers the years 2000 - 2007. The probability of moving is the sum of people moving within or across states, divided by the total number of households in that age group. Mobility within California is 11.8%, whereas average mobility (within or across states) is 13.6% across all ages. We calibrate move shocks to total mobility rates since move costs such as selling expenses and loss of Proposition 13 benefits are incurred regardless of the destination. The average moving rate is 0.29, 0.11, 0.09, 0.07, 0.07 for the age groups 21-34, 35-49, 50-64, 65-74, 75-88, respectively.

This mortgage rate corresponds to the average 30 year fixed mortgage rate from Freddie Mac since the 1970s, adjusted for inflation. Over the same time period, the real saving rate (based on one-year Treasury rate, 6-month CD rate, and 6-month Euro Dollar deposit rate) ranges between 1.4% and 2%. We picked the mid-point and set the saving rate to 1.7%.

In our benchmark calibration, we do not redistribute these transaction costs back to households. Rebating these costs in a way proportional to the income of the households has no effect on our main results.

In the U.S., higher LTV loans are generally available to borrowers, but banks and GSEs typically require mortgage insurance through Federal Housing Administration or private providers for higher LTV levels (Green and Wachter, 2005). Due to this additional cost, most borrowers don’t exceed 80% LTV. We compute the median LTV for purchase loans made in California in 2014 using loan level data from Federal Home Loan Bank System. The median LTV was 80% both for all homebuyers, and for first-time homebuyers. 49% of all first-time homebuyers had exactly 80% LTV. The model generated median LTV is 75% and 79% for all and first-time homebuyers, respectively, which are close to the empirical benchmarks.
summarizes the parameters used in our baseline calibration.

Table 1: Calibration of the Steady State

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi$ relative weight of $c$ in utility</td>
<td>0.67</td>
</tr>
<tr>
<td>$\sigma$ relative risk aversion</td>
<td>5</td>
</tr>
<tr>
<td>$\beta$ time discount factor</td>
<td>0.96</td>
</tr>
<tr>
<td>$\delta$ housing depreciation rate</td>
<td>2%</td>
</tr>
<tr>
<td>$\eta$ maximum loan-to-value</td>
<td>80%</td>
</tr>
<tr>
<td>$\varphi$ transaction cost of selling a house</td>
<td>6%</td>
</tr>
<tr>
<td>$r^m$ mortgage interest rate</td>
<td>4.2%</td>
</tr>
<tr>
<td>$r^d$ deposit interest rate</td>
<td>1.7%</td>
</tr>
<tr>
<td>$\tau^p$ property tax rate</td>
<td>1%</td>
</tr>
<tr>
<td>$\tau^s$ sales tax rate</td>
<td>10%</td>
</tr>
<tr>
<td>$\tau_{\eta_1}, \tau_{\eta_2}$ income tax parameters</td>
<td>0.312, 0.768, 1.5</td>
</tr>
<tr>
<td>$\pi_a$ prob. of advancing to next life-stage</td>
<td>9% for $a=1-4$; 5% for $a=5$</td>
</tr>
<tr>
<td>$w^a$ life-stage efficiency profile</td>
<td>0.58, 1.00, 1.25, 1.55, 0.4</td>
</tr>
</tbody>
</table>

The parameter $g$ in equation (2) captures the part of Proposition 13 that restricts the nominal growth in house values for tax purposes to 2% annually. In a world where house prices increase by more than 2% per year, this implies a decline in the real value of a house for tax purposes. We calibrate $g$ to capture this decline. Since the late 1970s, nominal per capita income in California has grown by 5.2%. In a model with exogenous growth of per capita incomes, nominal house values for tax purposes would have also grown by 5.2%. During the same period, house prices in California have increased by 6.9% on average, implying approximately a 5% decline in the real tax base due to Proposition 13. To capture the full effect of Proposition 13, we calibrate $g$ to -5%. As we will show in Section 4.1, this $g$ generates a decline in the effective property taxes by age that is similar to the one observed in the data, allowing us to capture the benefit of Proposition 13 for different age groups properly.

We implement Proposition 13 by keeping track of the number of years that an agent has stayed in the same house. We choose 30 grid points for the

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24 Bureau of Economic Analysis, regional NIPA data.
25 Data from FHFA house price index.
possible number of years an agent may stay at the same house. For each year
a house is unsold, we lower the value of the house for tax purposes by 5% up
to 30 years. The house value for tax purposes remains constant after 30 years.

The state variables in the dynamic programming problem consist of life-
stages $a$, (net) assets (where negative values represent saving, positive values
represent mortgage) $m_t$, housing $h_t$, employment state $e_t$, move shock $v_t$, and
the value of their house for tax purposes $B_t$. Average labor income is normal-
ized to 1. We have 5 grid points for life-stages, 76 grid points for mortgage
(ranging from -9.9 to 3.6), 6 values for housing (ranging from 1 to 4.5), 4 values
for idiosyncratic labor income, 2 values for move shocks, and 30 values for $B$,
all together resulting in 547,200 possible combinations of states.\footnote{In Section 5, we examine the sensitivity of our results to different assumptions about the grid on housing, the parameter $g$, and several other features of the economy.}

\section{Results}

We start this section by documenting the properties of the benchmark (Propo-
sition 13) economy and compare them against their data counterparts. Next,
we use this model economy to assess the consequences of introducing and
eliminating Proposition 13 on house prices, mobility, and welfare.

\subsection{Properties of the Model Economy}

In order to assess if this framework presents a good platform to conduct our
counterfactual experiments, we compare several key statistics generated by the
model against their data counterparts.

We start by comparing the homeownership rate and housing and non-
housing consumption generated by the model to their data counterparts. There
are many factors that influence the homeownership rate. While homeowner-
ship is financially advantageous, the existence of the down payment require-
ment and transaction costs present challenges to becoming a homeowner, es-
pecially in an environment with move shocks and income shocks. Thus, in
equilibrium, poorer and younger households are on average renters.\textsuperscript{27} The model generates an average homeownership rate of 55%, which is similar to the California rate of 56%.\textsuperscript{28} It also captures the increase in the homeownership rate by age, given in Table 2, reasonably well.

<table>
<thead>
<tr>
<th>Age</th>
<th>22-34</th>
<th>35-49</th>
<th>50-64</th>
<th>65-74</th>
<th>75-88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>0.29</td>
<td>0.62</td>
<td>0.77</td>
<td>0.81</td>
<td>0.80</td>
</tr>
<tr>
<td>Model</td>
<td>0.11</td>
<td>0.53</td>
<td>0.77</td>
<td>0.84</td>
<td>0.85</td>
</tr>
</tbody>
</table>

In Figure 1, we display housing and non-housing consumption over the life-cycle generated by the model. Empirical evidence presented in Jeske (2005) and Yang (2009) point out that the consumption profile of non-housing goods is hump-shaped while the consumption profile of housing is not. Yang (2009) shows that borrowing constraints are important for the slow accumulation of the housing stock early in life and transaction costs lead to the slow downsizing of the housing stock later in life. Due to similar channels, our model generates different life-cycle profiles for housing and non-housing consumption, consistent with the empirical evidence, despite the standard Cobb-Douglas utility function we have used.

The model also generates a reasonable house price, which was not one of the calibration targets. The ratio of median house price to median income in California has been roughly 5.1 since 1980.\textsuperscript{29} The same ratio generated by the model is equal to 5.04.

Given that the focus of our paper is on the effect of property taxation

\textsuperscript{27}Other modeling choices for generating renters and homeowners include assumptions about rental units depreciating faster or assigning higher utility to owning. We do not make those assumptions, since, as we will discuss in Section 3, our measure of the housing grid, which is directly based on data on the square footage of houses, together with the rest of the model features, generates a model economy that resembles the data fairly well.

\textsuperscript{28}California data are from IPUMS, ownership of primary residence, available for years 1990 and then 2000-2012. We report the averages for these years.

\textsuperscript{29}We compute the ratio for 1980, 1990, 2000, and 2009-2013 using median house price and median household income data (all households) for California from the Census Bureau. The ratio was 4.6, 5.5, 4.5, and 6 in those years, respectively.
across individuals, it is important that the model’s calibration is consistent with the actual tax burden faced by the agents in the economy. We are particularly interested in capturing the cross sectional differences in property taxes paid by agents with different housing tenure and age. Table 3 compares the effective tax rates by housing tenure length for residents of California with their counterparts in the model.\footnote{Following Ferreira (2010), we use the IPUMS data and construct the effective tax rates as the average of property taxes paid divided by house values for each household for all the available years between 1990 and 2007 in California.}

<table>
<thead>
<tr>
<th>Housing Tenure (years)</th>
<th>2</th>
<th>3-4</th>
<th>5-9</th>
<th>10-19</th>
<th>20-29</th>
<th>30+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>0.86</td>
<td>0.77</td>
<td>0.66</td>
<td>0.60</td>
<td>0.40</td>
<td>0.26</td>
</tr>
<tr>
<td>Model</td>
<td>0.95</td>
<td>0.90</td>
<td>0.74</td>
<td>0.54</td>
<td>0.32</td>
<td>0.23</td>
</tr>
</tbody>
</table>

In the model the effective tax rate is a declining function of housing tenure, as the value of the house for tax purposes remains lower than its actual market value, where the rate of decline is calibrated to the average growth in California house prices. We find that the model captures the magnitude of the decline in effective tax rates quite well. The effective tax rate declines from nearly 1% for new homeowners to roughly a quarter of 1% for homeowners with 30+ years of tenure length.\footnote{The largest difference between the data and model generated effective tax rates is for}
Figure 2 displays the effective property tax rate by age in the model and the data. The declining pattern of tax rates by age reflects one of the implications of Proposition 13. Older households, predominantly people with longer housing tenure, pay lower effective taxes. The model captures the magnitudes of the tax burden by age reasonably well, implying that the model generates realistic housing tenure behavior over the life cycle. However, similar to the results in Table 3, in the data there is a small benefit of Proposition 13 even for the youngest agents whose effective tax rate is slightly below 1%, probably due to inherited tax bases.

To further investigate if our model economy captures the benefits of Proposition 13 properly, we examine the magnitude of property taxes paid as a percent of income by age with and without Proposition 13. The first panel in Figure 3 presents the actual data for property taxes paid as a percent of income as well as results of a counterfactual case where we apply a 1% flat property tax rate to the reported house values and divide it by income. The growing difference between the two lines captures how the benefits of Propo-

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Footnotes:

32The data is from IPUMS where we take the average of property taxes divided by income for each household in California over all the available years between 1990 and 2007.

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position 13 increase with age in the data. For example, abolishing Proposition 13 results in property taxes to increase from roughly 5% of income to 10% of income for an 80-year-old person.

Figure 3: Property Tax/Income Over the Life-Cycle

The second panel in Figure 3 displays property taxes as a percent of income for the economy with Proposition 13 simulated from the model, and the counterfactual case with a 1% flat property tax rate. The magnitude of the tax to income ratio is slightly smaller in the model than in the data. However, the relative gain due to Proposition 13 in the model is similar to its counterpart in the data. For example, for an 80-year-old, elimination of Proposition 13 leads to an 82% increase in their property tax to income ratio (from 4.3% to 7.8%).

There is a dimension along which the model does not mimic the data well. The Gini coefficients generated by the model for income (0.31) and wealth (0.66) are lower than their data counterparts. According to Castaneda, Díaz-Gimenez, and Ríos-Rull (2003), the earnings and wealth Gini in the data are 0.63 and 0.78, respectively. Since the main impact of Proposition 13 is expected to be across generations, however, we have chosen a simpler income process than the ones that are capable of mimicking the income and wealth distribution in the U.S., such as the income process used in Castaneda, Díaz-Gimenez, and Ríos-Rull (2003).

Overall, we conclude that our framework provides a reasonable laboratory for examining the implications of Proposition 13 as well as the potential consequences of its elimination on house prices, mobility, and welfare.


4.2 Economies with and without Proposition 13

In this section we use our calibrated model to inform us about the consequences of introducing and eliminating Proposition 13 on housing allocations and welfare of the agents. We start with a summary of the steady state characteristics of economies with and without Proposition 13. Next, we examine the impact of eliminating Proposition 13 on housing allocations, house prices, and welfare, taking into account the behavior of the agents during the transition to the new steady state.

4.2.1 Steady-State Comparisons

Introduction of Proposition 13

Proposition 13 introduces two major changes to property taxation. It reduces the property tax rate from the average pre-1978 level of 2.5% to 1% and limits the growth rate of the value of the house for tax purposes following its purchase. The second feature results in effective tax rates that decline by housing tenure and therefore by age leading to an average effective tax rate of 0.7%. We label this case as the Proposition 13 economy (Post-1978 case). We normalize the price in this economy to 100 and present all other house prices relative to this benchmark.

In the first row of Table 4, we present the economy prior to Proposition 13, where the property tax rate is 2.5% and property values for tax purposes are equal to their market values. The differences between the pre-1978 and post-1978 house prices reflects the impact of both effects of Proposition 13. We find that the implementation of Proposition 13 leads to a 15% increase in house prices.

In order to disentangle the effects of the two features of Proposition 13 on house prices, we examine a counterfactual case (Experiment 1) where the only change relative to the pre-1978 case is the reduction in the property tax rate from 2.5% to 0.7%, the average effective tax rate under Proposition 13. Thus, total revenues collected in the Proposition 13 economy and the economy in Experiment 1 are the same; the only difference between the two cases is
that in Experiment 1, the value of a house for tax purposes is not related to housing tenure (property taxes are based on the current market value of the property and not the purchase price of the house). We find that in this case, house prices increase by 19.5% compared to the Pre-1978 case (from 87 to 103.7), which reflects the present value of the decline in the future property tax payments.\textsuperscript{33} This comparison reveals that the increase in house prices due to the introduction of Proposition 13 would have been slightly higher if it were not for the link between property assessments and housing tenure, and the distortions due to Proposition 13 limit the growth of house prices to 15%.

<table>
<thead>
<tr>
<th>Table 4: Steady States: Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>House Price</strong></td>
</tr>
<tr>
<td>Pre-1978 (2.5% flat property tax)</td>
</tr>
<tr>
<td><strong>Post-1978 (Proposition 13)</strong></td>
</tr>
<tr>
<td>Experiment 1 (0.7% flat property tax)</td>
</tr>
<tr>
<td>Experiment 2 (sales tax)</td>
</tr>
<tr>
<td>Experiment 3 (income tax)</td>
</tr>
</tbody>
</table>

To understand the distortion created by Proposition 13 over the life-cycle, we compare the housing allocations in the Proposition 13 economy to those in Experiment 1 (without Proposition 13). Since moving implies the loss of their tax benefits under Proposition 13, agents on average are more hesitant to move to larger homes as their incomes rise, and downsize in retirement when their incomes fall. This mechanism leads to generally higher housing consumption in retired agents, and rather steep housing allocations over the life-cycle. It is also possible that for some of the older agents who are still working, Proposition 13 leads to a smaller housing consumption than desired. To capture the distortions caused by Proposition 13, for each agent every period we measure the percent deviation (in absolute value) in housing consumption from the economy in Experiment 1. In Figure 4, we plot the average distortion by age.

\textsuperscript{33}The capitalization effect of the decrease in the property tax rate found in this experiment is consistent with the empirical estimates in Rosen (1982), who reports that across different jurisdictions in California, each dollar reduction in property taxes due to Proposition 13 led to a seven dollar increase in property values.
As shown in Figure 2, with Proposition 13, the effective property tax rates decline by age. Consequently, the willingness of individuals to change their housing goes down by age. Since all agents start life as renters, we observe zero distortions for the youngest agents. Distortions increase and reach about 10% of housing consumption by the age of 90.

Figure 4: Distortion in Housing Allocations Over the Life-Cycle

Elimination of Proposition 13

In the following counterfactual experiments, we compare the Proposition 13 economy to three others where we keep the total revenues collected constant but eliminate the link between the value of the house for tax purposes and housing tenure. This is achieved by a 0.7% property tax rate in Experiment 1. In the other two experiments, Proposition 13 is eliminated and replaced with economies with a 1% flat property tax rate, while total tax revenues are kept constant by lowering the sales tax (Experiment 2) or the income tax rate (Experiment 3) below their benchmark levels. In Experiment 2, a reduction in the sales tax rate from 10% to 7.9% allows government revenues to stay unchanged. In Experiment 3, the effective state income tax rate for the median income household is reduced from 3.5% to 2.1%.\textsuperscript{34} Through these counterfactual experiments we assess the impact of the elimination of the Proposition 13

\textsuperscript{34}We run this experiment by reducing the state income tax collection of all households at the same rate, by changing $\tau_{m}$ to 0.292. Note that this parameter captures both federal and state income taxes.
provision that effectively links property taxes to housing tenure.

Our results, reported in Table 4 indicate small increases in house prices relative to Proposition 13 levels for all these experiments. Among our three revenue-neutral experiments, house prices turn out to be highest in the lower property tax case (Experiment 1), where elimination of Proposition 13 leads to a 4% increase in house prices. This increase in house prices is entirely due to the elimination of the link between the property tax assessments and housing tenure, since effective average property taxes are the same in these two economies. In Experiments 2 and 3, the property tax rate is higher at 1%, while the other taxes are lower. Overall, all the price changes we find are quite modest.

The results of the revenue neutral experiments reinforce our interpretation that the increase in house prices that happened after the implementation of Proposition 13 were mainly due to the large decline in the property tax rate, and the elimination of Proposition 13 in a revenue-neutral way is unlikely to lead to significant changes in house prices.

Table 5: Steady States: Mobility

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>Moving rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average 22-34</td>
</tr>
<tr>
<td>Pre-1978 (2.5% tax)</td>
<td>14.1</td>
</tr>
<tr>
<td>Post-1978 (Prop. 13)</td>
<td>13.7</td>
</tr>
<tr>
<td>Experiment 1 (0.7% tax)</td>
<td>14.2</td>
</tr>
</tbody>
</table>

35 In the Appendix, using a simple model that abstracts from Proposition 13 and transaction costs, we examine the relationship between house prices and different taxes analytically. We show that, everything else being equal, changes in the sales tax rate have no effect on house prices, whereas lower property and income tax rates lead to higher house prices. Reduction in the property tax rate is entirely capitalized in house prices, leading to the highest house prices, while a lower income tax rate is partially captured by house prices. On the other hand, with Proposition 13, the link between housing tenure and property assessments creates a distortion in housing allocations that depresses house prices. The overall change in house prices due to elimination of Proposition 13, therefore, reflects the relative impact of the changes in different taxes and the elimination of this distortion.

36 It is important to note that our assumption about a fixed housing supply allows us to capture the upper-bound on the changes in house prices. If the housing supply were allowed to adjust, the change in house prices would be even smaller.
In Table 5, we examine the consequences of Proposition 13 on mobility. The moving rate, measured as the number of households that move in a given year as a fraction of total number of households, is 13.7% for the Proposition 13 economy. As explained in the calibration section, exogenous move shocks are used to calibrate the economy with Proposition 13 to generate moving rates that mimic the data and assumed to stay the same in all experiments. Comparison of the moving rates in the Pre-1978 economy to Post-1978 economy reveals the impact of Proposition 13 on mobility. We find that Proposition 13 leads to a modest 3.3% decrease in the moving rate, from 14.1% to 13.7%.

Why is the effect of Proposition 13 on mobility so small? We conduct a number of counterfactual exercises to investigate the reasons behind the small change in mobility. First, we examine if this result is sensitive to our specification of the move shocks. These shocks force agents into moving, hence increasing mobility. However, since the agents anticipate the possibility of these forced moves in the future, they reduce the frequency of their planned moves, and coincide their moves with the move shocks they receive. To assess the impact of this feature we solve an economy with no move shocks. In this case, the mobility is 7.23% before Proposition 13 and declines to 5.56% once it is introduced. Thus, without the move shocks the overall mobility is low and the impact of Proposition 13 on mobility is slightly bigger than the benchmark case. Next, we investigate the role of transaction costs by removing them from the previous economy. In this case, with no transaction costs or move shocks, the move rate before Proposition 13 is 22.9%. The introduction of Proposition 13 has a big effect where mobility declines to 10.4%. We conclude that the impact of Proposition 13 on mobility in the benchmark is small due to the existing distortions in the economy, in particular the transaction costs. These findings help explain why it has been challenging to tease out the lock-in effect of Proposition 13 in empirical studies.

Mirroring the impact of its introduction, the elimination of Proposition 13 also results in a small overall increase in mobility, about 4% (from 13.7% to 14.2%), for all the revenue-neutral cases considered. While the overall effect is quite small, the effects on mobility increase with age, reaching 10% for the
older agents.\footnote{In Section 5, we provide the results of eliminating Proposition 13 in an economy with no transaction costs and no involuntary move shocks.}

Finally, we examine the welfare implications of being born into an economy with or without Proposition 13 by asking how much an individual’s non-housing consumption has to be increased (keeping housing constant) in an economy with Proposition 13, so that his expected future utility equals his utility under the economy without Proposition 13.\footnote{Since in this model there is no productive role for the government, we refrain from making welfare statements except for revenue-neutral cases.} We find that the welfare gains of being born into an economy without Proposition 13 is 0.3\% in the case of lower property taxes (Experiment 1), 1.2\% in the case with lower sales taxes (Experiment 2), and 1\% in the case with lower income taxes (Experiment 3). The welfare benefits, especially in the latter two cases, are sizable, and stem mostly from the decline in the tax burden while the agents are young and borrowing constrained. The lower welfare benefit obtained in the case with lower property taxes (Experiment 1) is partly due to the larger increase in house prices, which is disliked by most agents in this framework.\footnote{Almost all agents dislike higher property prices because housing is a consumption good and higher house prices imply higher consumption prices. Owning a house does not provide a complete hedge against higher consumption prices because of proportional ownership costs such as property taxes and maintenance (depreciation) and uncertain life spans.}

All three revenue-neutral cases allow agents to allocate housing more optimally over their life-cycle, removing the distortion due to Proposition 13. However, the tax implications of these three cases over the life-cycle, as well as their implications on house prices, are different. Figure 5 displays the average total taxes paid as a fraction of income, by age, in the economy with Proposition 13 versus the economies without Proposition 13 for each of the revenue-neutral cases. Overall, elimination of Proposition 13 leads to a significant decline in the tax burden faced by young individuals, especially when revenue-neutrality is achieved via lower income tax rates (Experiment 3). For an agent in her early 20s, there are 0.7 to 1.1 percentage point declines in the tax burden in the economies without Proposition 13, which contribute to the size of the welfare gains. Reform with lower property taxes leads to the
smallest decline in the tax burden of the younger agents, which makes reform less desirable for those households. Increasing house prices further reduce the attractiveness of this reform. Reform with sales tax and income tax lead to similar drops in the tax burden of the young. While house prices rise modestly in both cases, a slightly lower increase in the sales tax case makes this the most attractive reform for the young. On the other hand, the tax burden of the older agents increases significantly in all cases, 1.5 to 3 percentage points for the average 90 year old agent.

Figure 5: Tax Burden Over the Life-Cycle

So far, we assumed a constant housing supply, partly because we are interested in capturing the full impact of Proposition 13 on house prices. In the absence of quantity adjustments, house prices absorb all the changes in housing demand resulting from changes in the tax regime. The price changes we report in Table 4, therefore, represent an upper bound. However, housing supply may change, especially in the long run. We find that a 3.7% increase in housing supply is needed to keep prices constant when revenue neutrality is achieved via property taxes. With a flexible housing supply, the welfare gain of being born into an economy without Proposition 13 increases to 2.2% in Experiment 1 since the young agents no longer face the negative effects of higher prices. The welfare gains are 1.8% and 1.9% for Experiments 2 and 3. Overall, all the welfare effects we find are quite large.

40Supply has to increase 1.8% in the sales tax case, and 3% in the income tax case to keep the prices constant.
Of course, steady state welfare results do not properly capture the level of support that may be generated for the elimination of Proposition 13 at a given point in time. To examine this issue further, we turn our attention to modeling transitions from a steady state with Proposition 13 to another one without Proposition 13.

4.2.2 Transitions

We now assume that the economy starts in a steady state where property taxes are determined under Proposition 13. At the beginning of period 2, the government announces an unexpected change in tax policy and eliminates Proposition 13 and starts collecting property taxes based on the current market value of the property. From that period on, agents adjust their behavior, anticipating a future where effective property tax rates remain flat. After a number of periods, the economy converges to a new steady state without Proposition 13. During the transition, agents change their housing allocations to reach their optimal allocations in a world without Proposition 13.

House prices along the transition takes different paths across experiments. In Experiments 2 and 3 (sales and income tax) prices converge to new equilibrium levels in a few periods. In Experiment 1 (property tax), where the price impact is largest, the price overshoots in the first few periods, but reverts back to its new equilibrium level over time. Convergence takes roughly 20 periods. Changes in housing allocations over the life cycle occur at different speeds, while most changes are completed by the time prices converge to the new equilibrium.

Next, we evaluate the welfare of agents with and without reform. We quantify the welfare effects of reform for different individuals by using the consumption equivalent variation measure along the transition. The welfare effect of a reform for an individual of type \((a_t, m_t, h_t, e_t, v_t, B_t)\) is found by asking how much this individual’s non-housing consumption has to be increased in all future periods so that his expected future utility with Proposition 13 equals his utility under that reform. Given the form of the utility function, consumption compensation, as a fraction of lifelong consumption, is calculated.
as:

\[ \text{EV}(a_t, m_t, h_t, e_t, v_t, B_t) = \left( \frac{V_R(a_t, m_t, h_t, e_t, v_t, B_t)}{V_{NR}(a_t, m_t, h_t, e_t, v_t, B_t)} \right)^{\frac{1}{\chi(1-\gamma)}} \]

where \( V_R \) and \( V_{NR} \) represent the value function in economies with and without reform, respectively. We report both the percent of agents at each age who are in favor of the reform (those whose utility is higher under the reform) and the consumption compensation by age.

The first panel of Figure 6 summarizes the percent of agents in favor of the reform and the second panel displays the average consumption compensation needed to equate the welfare in the Proposition 13 economy with welfare in alternative regimes, by age, for three different revenue-neutral cases. We find that the reform that receives the highest support for all age groups is the one where the sales tax rate is reduced to keep tax revenues constant (Experiment 2). While the youngest agents favor the transition, the reform loses the approval of the majority in all age cohorts over the age of 45. The welfare benefit of the reform is around 1.2% additional consumption per year for 21-year-olds. As reported in Table 6, 54% of the agents who are alive at the time of transition favor elimination of Proposition 13 in this case.\(^{41}\)

When revenue neutrality is achieved by reducing property taxes (Experiment 1), only 12% of the households support it. One major difference between this case and the other two reforms is the lack of support from the younger individuals. This is mainly due to the fact that house prices initially overshoot in transition, immediately rising by 5%, and gradually decline to the new steady state levels, which are 3.7% above the Proposition 13 prices. All agents, but especially the young agents who start life as renters, and others who want to move to larger houses are adversely effected by the increase in house prices, reducing the welfare benefits of the reform. The average welfare benefit is slightly negative for all age cohorts.

Older agents have very low levels of support for the reform in all three

\(^{41}\)In the model economy all agents are assumed to vote, while in the data, voter turnout increases by age. On the other hand, older people are slightly overrepresented in the model economy since we abstract from population growth. Correcting for generation size and voting patterns in California results in 54.8% approval of reform.
cases. But the welfare effect of the reform on the older agents is noticeably lower in the case where the labor income tax rate is reduced to keep tax revenues constant (Experiment 3). Lowering the labor income tax rate does not benefit the elderly since Social Security income is not taxed. Consequently, welfare effects of the reform are around -2.5% for the older agents. The overall support for the reform is 36% in this case.

Figure 6: Welfare Comparisons Over the Life-Cycle

As discussed before, lower property tax rates generate an increase in house prices, hurting especially the renters and younger individuals. This results in lower support for reform, especially by the younger agents, when revenue neutrality is achieved through a lower property tax rate as opposed to a lower sales tax rate. If we allow housing supply to change so that house prices remain constant, the overall support for the reform goes up to 60% for the property tax, 58% for the sales tax, and 42% for the income tax cases.

In Table 6, we report more information on the types of agents who are in favor of the reform in our benchmark cases where house prices are allowed to change. Renters favor the reform in sales and income tax cases, whereas they completely oppose it in the property tax case. Owners in general have very low support levels. Among the owners, the level of support depends on the value of their house for tax purposes ("low base" versus a "high base" in rows four and five of Table 6). Those with a low tax base, that is, the individuals whose house value for tax purposes is low, are less supportive of the reform.
It is also interesting to examine the last three rows, where we present the level of support for the reform from different labor income groups. High income agents are exclusively homeowners, who have very low support levels for the reform under all the revenue neutral schemes. Low income households support the reform if it leads to a reduction in sales taxes. These households are either young renters, or the retirees. Renters are not in favor of the reform with lower property taxes since it leads to higher house prices. Retirees don’t support the reform with income taxes since they don’t pay those taxes. Middle income households, many of which are still renters, support the reform with sales and income taxes, but not the property taxes.

<table>
<thead>
<tr>
<th>Table 6: Percent in Favor of Eliminating Prop. 13</th>
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<tbody>
<tr>
<td>sales tax</td>
</tr>
<tr>
<td>All</td>
</tr>
<tr>
<td>Renters</td>
</tr>
<tr>
<td>Owners</td>
</tr>
<tr>
<td>Low Base</td>
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<tr>
<td>High Base</td>
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<table>
<thead>
<tr>
<th>Income</th>
<th>sales tax</th>
<th>property tax</th>
<th>income tax</th>
</tr>
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<tbody>
<tr>
<td>Low</td>
<td>63</td>
<td>27</td>
<td>30</td>
</tr>
<tr>
<td>Middle</td>
<td>78</td>
<td>3</td>
<td>72</td>
</tr>
<tr>
<td>High</td>
<td>21</td>
<td>5</td>
<td>7</td>
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</table>

Overall, our findings highlight the importance of policies surrounding the reform if Proposition 13 were to be eliminated. We find that steady state welfare gains from the reform can be quite large and stem mostly from the decline in the tax burden while young and borrowing constrained. However, the level of support for reform is usually low once transitions are taken into account. For example, even though a reduction in the income tax rate generates large welfare benefits at the steady state (1% of consumption per year), it receives support from only 36% of the agents along the transition. In this case, the transition period is especially painful for the middle-aged and older individuals since they lose all their benefits without much in return. Even though future generations who are born into the world without Proposition 13 will be able
to optimize over their expected lifetime utility and be better off, the reform currently has little chance of passing.

We show how the welfare gains and the level of support varies across different ages and different revenue-neutral cases along the transition. In most of our calibrations, a reduction in the sales tax rate generates the highest level of support, slightly passing the 50% threshold, while a decline in the property tax rate generates the least amount of support. Lastly, if property prices increase as a result of the reform, this reduces the overall support, especially of the renters and the young individuals, the main groups who normally benefit from such reform.

5 Sensitivity Analysis

In this section, we report the sensitivity of the results to our calibration as well as to some of the modeling choices we have made. We find that elimination of Proposition 13 leads to small changes in house prices and mobility under many different parameterizations. The main reason for this finding is the existence of transaction costs and moving shocks, which preempt the effect of Proposition 13 on housing allocations. In a world without these frictions, Proposition 13 does lead to much larger changes in prices and mobility. The percent of voters in support of elimination primarily depends on the price implications of the reform. Below, we summarize a number of different experiments in more detail.

One of the parameters that is potentially important for our results is the choice of $g$, which governs the decline in the effective property tax rate. Proposition 13 is especially valuable to agents who have owned their house for a long time during periods of high growth in housing prices. Higher $g$ (in absolute value) in the model corresponds to periods of high growth in house prices where agents who live in the same house enjoy larger tax benefits due to Proposition 13. In our benchmark calibration, we chose $g = -5\%$ based on the difference between the nominal house price growth rate observed in the data and 2%, the growth in tax assessments with Prop 13. In the third and fourth columns of
Table 7, we report the results for a lower (-3%) and a higher (-7%) $g$, representing periods of lower and higher growth rates in housing prices. We normalize the price level for the benchmark case presented in the first row to 100, and scale all other prices relative to this benchmark. Our findings indicate that house prices, mobility, and the amount of support generated for the elimination of Proposition 13 are generally similar for the three values for $g$. Different values of $g$ simply change the magnitude of the losses and benefits for agents. However, it does not change the fraction of agents that are effected positively or negatively. Consequently, the support levels remain the same.

<table>
<thead>
<tr>
<th>Table 7: Sensitivity Analysis</th>
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<tr>
<td>Benchmark</td>
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<tr>
<td>Proposition 13</td>
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<tr>
<td>Price</td>
</tr>
<tr>
<td>Mobility</td>
</tr>
<tr>
<td>Elimination of Proposition 13</td>
</tr>
<tr>
<td>Sales Tax</td>
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<tr>
<td>Price</td>
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<tr>
<td>Mobility</td>
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<td>In favor %</td>
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<tr>
<td>Property Tax</td>
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<tr>
<td>Price</td>
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<td>Mobility</td>
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<td>In favor %</td>
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<tr>
<td>Income Tax</td>
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<tr>
<td>Price</td>
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<tr>
<td>Mobility</td>
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<td>In favor %</td>
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</table>

Another feature of the model economy that is potentially important for our results is the assumption about move shocks. In the second to last column of Table 7, we present the results for an economy without the exogenous move shocks. The mobility rate found in this case (5.7%) is lower than the one observed in the data (13.6%). Moves by renters, who do not incur transaction
costs upon moving, account for a large part of this mobility. Without ex-
ogenous move shocks, elimination of Proposition 13 leads to a larger increase
in mobility compared to the benchmark case. Overall mobility goes up by
roughly 20%, but the increases are much larger for the middle-aged and older
agents (50% to 80%). House price patterns and the percent of voters in favor
of elimination are similar to the benchmark case.

In the last column of Table 7, we present an economy where households are
not subject to any transaction costs or move shocks. In this economy, Propo-
sition 13, along with the usual borrowing constraints, are the only frictions.
The moving rate (10.4%) is higher than the case with no move shocks, but it
remains below the mobility observed in the data. Elimination of Proposition
13 has larger effects compared to other cases. Prices go up in all revenue neu-
tral elimination cases. Since almost all distortions in housing allocations are
due to Proposition 13, its elimination leads to bigger changes in allocations.
Better allocations push prices higher, and mobility increases around 60% fol-
lowing the reforms. A narrow majority of the agents support the reform in the
sales tax case, but most agents oppose it in the other two cases, where house
prices spike during the first few periods of the transition.

In addition to the sensitivity analysis presented so far, we checked the ro-
bustness of our findings to some preference parameters, borrowing constraints,
and our choice of the housing grid points while solving the model. An economy
with a finer housing grid generates very similar results for both the Proposi-
tion 13 economy and the alternative regimes.\textsuperscript{42} The results are also robust to
using a lower risk aversion parameter. Lower borrowing constraint (maximum
loan-to-value ratio of 90%) leads to a higher homeownership rate (66%) and
slightly lower support for the elimination of Proposition 13 (43% in sales tax
case, lower in others).\textsuperscript{43}

It is important to note that elimination of Proposition 13 generates low

\textsuperscript{42} Very few agents choose house sizes of four or above. Therefore, extending the maximum
house size beyond 4.5 also has no impact on our results.

\textsuperscript{43} Indeed, following several years of declining collateral constraints, the homeownership
rate in California peaked at 60.2% in 2006. After the financial crises, both the collateral
constraints and the homeownership rate reverted back to their long-run averages.
levels of support in the model, despite the fact that our experiments are conducted in a revenue-neutral manner. In California, many associate elimination of Proposition 13 with an increase in property tax collections. We also examine the consequences of eliminating Proposition 13 without maintaining revenue-neutrality. In these counterfactuals, we set the property tax rate at 1% as before and kept income and sales tax rates unchanged. Eliminating the link between housing tenure and property taxes implies that individuals of all ages now face a 1% property tax rate, resulting in higher effective tax rates faced especially by the older agents. In this case, for all the models we have examined, elimination of Proposition 13 generates almost no support.

6 Conclusions

In this paper, we study the implications of Proposition 13 on house prices, mobility, and welfare of the households in an economy populated with overlapping generations of agents. The introduction of Proposition 13 leads to two major changes in property taxation. It reduces the property tax rate from 2.5% to 1% and links the value of the house for tax purposes to housing tenure. The second feature results in effective taxes that decline in housing tenure and therefore by age, and distorts housing allocations. In the model economy, the introduction of Proposition 13, which incorporates both of these effects, leads to a 15% increase in house prices and a 3.3% decrease in the moving rate. The increase in the house prices mainly reflects the present value of the decline in property tax payments.

We use this framework to examine the consequences of eliminating Proposition 13 on housing allocations and welfare. In these experiments, we keep the total tax revenues constant and just eliminate the link between the value of the house for tax purposes and housing tenure. We find that such a reform is likely to have small effects on house prices and mobility. The main reason for this finding is that the distortions caused by the lock-in effect of Proposition 13 pale in comparison to the distortions caused by the existence of transaction costs and moving shocks. The welfare implications of reform, how-
ever, are quite heterogenous among the renters, home owners and individuals of different ages. While the benefits of being born into an economy without Proposition 13 is high, support for its elimination is quite low and depends on how revenue neutrality is achieved. Keeping revenues constant by lowering the sales tax generates the most amount of support, while achieving revenue neutrality via a reduction in property tax rates generates the least amount of support, particularly due to its positive impact on house prices.

There are several other interesting questions related to Proposition 13 that we do not investigate in this paper. The relationship between the state and the local governments, as well as between the federal and the state government in California, has changed after Proposition 13. The resulting political economy questions and whether or not Proposition 13 was an effective way for voters to curb government spending are beyond the scope of this paper. Another important issue, the impact of Proposition 13 on commercial real estate, is left for future research.

References


In order to understand the effect of different taxes on the price of housing, we present a simple infinite horizon framework without any transaction costs, Proposition 13, or income tax deductibility of property taxes.

A representative agent chooses housing, $h_t$, and non-housing consumption, $c_t$, to maximize:

$$\sum_{t=0}^{\infty} \beta^t u(c_t, h_t)$$

where $0 < \beta < 1$ is the subjective time discount factor. The individual with an income $y_t$ faces income taxes, $\tau^i$, sales taxes, $\tau^s$, and property taxes, $\tau^p$. Let $m_{t+1}$ be the agent’s mortgage holdings (if positive), or savings (if negative)
at the beginning of period $t + 1$, $p_t$ be the price of a unit of housing, and $r$ the real interest rate. The budget constraint of the individual is given by:

$$y_t(1 - \tau^i) + (1 - \delta)p_t h_t + m_{t+1} = c_t(1 + \tau^s) + p_t h_{t+1} + (1 + r(1 - \tau^i))m_t + \tau^p p_t h_t.$$  \hfill (14)

At the steady state, the first order conditions of this maximization problem result in:

$$\frac{u_h}{u_c} = \frac{(r(1 - \tau^i) + \delta + \tau^p)p}{1 + \tau^s}. \hfill (15)$$

With the Cobb-Douglas utility function in $\tilde{c}_t = [c_t^{\chi} h_t^{1-\chi}]$, we get:

$$\frac{u_h}{u_c} = \frac{1 - \chi}{\chi} \frac{c}{h}. \hfill (16)$$

In this framework, expenditure shares of housing and non-housing consumption remain constant. Combining equations 15 and 16 yields:

$$\frac{1 - \chi}{\chi} \frac{c}{h} = \frac{(r(1 - \tau^i) + \delta + \tau^p)p}{1 + \tau^s}.$$ 

Assuming a zero net supply of mortgages and substituting this first order condition in the budget constraint results in a relationship between house prices and different taxes:

$$p = \frac{(1 - \chi)(1 - \tau^i)y}{h(\delta + \tau^p + \chi(r(1 - \tau^i)))}. \hfill (17)$$

We can make several observations based on equation 17, under the assumption of a fixed supply of housing and income. First, we can see that house prices are not a function of the sales tax rate. This is due to the constant expenditure shares of housing and consumption goods. The decline in the sales tax results in higher consumption, keeping the total expenditures on consumption goods unchanged. Consequently, it has no effect on housing consumption or price. Second, a decline in the property tax rate is capitalized
in house prices. With constant housing supply, a lower property tax leads to an offsetting increase in house prices and maintains the constant expenditure share of housing. Finally, a lower income tax rate leads to higher disposable income and higher total expenditures. With constant expenditure shares and housing supply, only a part of the increase in expenditures is capitalized in higher house prices. Lower income taxes lead to a smaller increase in house prices compared to the property taxes since part of the effect is absorbed in the non-housing consumption.

7.2 Data

Age-Earnings Profile and Transition Matrices

We target the earnings profile for the median earners for ages 25 through 60 such that, the age-income profile for the median earners in the model mimics its counterpart in the data. We calculate the earnings efficiency as \([0.77, 0.86, 1.06, 1.13, 1.25, 1.21, 1.05, 0.9]\), for ages \([25, 30, 35, 40, 45, 50, 55, 60]\), respectively, from mean earnings of P50 (median lifetime income) group, provided by Guvenen et al. (2015). In our calibration of \(w^a\), we search over different values of \(w^a\) until we minimize the mean square errors between the model-generated income profile for medium-income agents and the data. Our calibration yields the income profile plotted in Figure 7.

The transition function \(\Pi(a, a')\) for life-stages is given by:

\[
\Pi(a, a') = \begin{bmatrix}
0.91 & 0.09 & 0 & 0 & 0 & 0 \\
0 & 0.91 & 0.09 & 0 & 0 & 0 \\
0 & 0 & 0.91 & 0.09 & 0 & 0 \\
0 & 0 & 0 & 0.91 & 0.09 & 0 \\
0 & 0 & 0 & 0 & 0.92 & 0.08 \\
\end{bmatrix}.
\]

The transition function for the earnings process is given by:
Figure 7: Income Profile for the Median (Lifetime Income) Household, Data and Model

\[
\Gamma(e, e') = \begin{bmatrix}
0.84 & 0.16 & 0.00 & 0.00 \\
0.16 & 0.64 & 0.20 & 0.00 \\
0.00 & 0.20 & 0.64 & 0.16 \\
0.00 & 0.00 & 0.16 & 0.84
\end{bmatrix}.
\]

Housing Grid

We use data on the square footage of a unit for homeowners and renters to help us calibrate the housing grid. According to the American Housing Survey (U.S. Census Bureau), the average square footage of homes for homeowners in 2013 was 2,014. For renters, the average was 1,185 square feet. Overall, the average size of a house was 1,739 square feet. To calculate the available square footage, we took the midpoint of the home size ranges given in Table C-02-AO.
California Data

We use Integrated Public Use Microdata Series (IPUMS-CPS) to construct the effective tax rates and property taxes to income for all the available years between 1990 and 2007.

Coding for property taxes: Each household (HH) is given a code (ranging from 00-69). Most of these codes designate a particular tax bucket (e.g., “$50-99,” “$100-149,” “$150-199,” etc.). These buckets designate the total property taxes that a HH paid in a particular year. In our data, we take the average of the extreme points of a bucket as the actual total property taxes paid by a HH in a particular year. Certain codes do not designate a tax bucket. For instance, code 00 stands for “N/A,” and code 01 stands for “None.” These missing values are removed from the data. Code 57 does not link to a bucket, but rather to the value of “$4,500.” Naturally, we take this as the total property tax value for any HH with the code 57. Finally, code 69 is for total property tax values of “$10,000+.” Because there is no upper limit for code 69, we assume, for simplicity, that any HH coded as 69 pays total property taxes of $10,001.

Coding for HH values: As before, each HH is given a 7 digit code. Most of these codes designate a particular range of HH values (e.g., “Less than $500,” “Less than $999,” “$5,000-7,499,” “$7,500-9,999,” etc.). As before, for those buckets with lower and upper limits, we take the average of the limits as the HH’s value in a particular year. For those codes that do not have lower or upper limits (e.g., “Less than $500,” “$35,000+,” “$50,000+,”) we simply assume the HH value to be the closest integer to the provided limit. For example, a code that links to values of “Less than $500” would be assumed to indicate a HH value of $499; a code that links to values of “Less than $999” would be assumed to indicate a HH value of $998; a code that links to values of “$35,000+” would be assumed to indicate a HH value of $35,001, and so forth. Code 0000000 indicates a $0 HH value; code 9999999 stands for “N/A.” These last two codes are removed from the data.

Calculation of effective property tax rates: For each HH, effective property tax rates are calculated as total property taxes over HH value. We sort, in ascending order, effective property tax rates according to the maximum of the
age of HH head and spouse. If only one age is provided (HH head or spouse), we take that age. If neither age is provided, the HH is removed from the data. We have data for the year 1990 and then for the years 2000-2011. We do not include the years 2008-2011 as these years are affected by the financial crisis. Therefore, for the years 1990 and 2000-2007, we take the average across all years for each age from 20 and upwards.

Calculation of Property tax/income and the counterfactual: Property tax/HH income is simply the aforementioned total property taxes divided by HH income. HH income values are directly provided in IPUMS without any coding scheme. Naturally, those HHs that have an income value of 0 are removed from this data. Note that we use a particularly conservative assumption and remove all HHs with property tax/HH income ratios greater than 7 and less than 0. For the counterfactual, we take 1% of the aforementioned HH values as the numerator, and HH income as the denominator. As before, we sort the data by age from 20 upwards. Then, for each age, we take the average across the years 1990 and 2000-2007.

7.3 Computation Method

We solve the steady state decision rules for the economy with Proposition 13 and the one without. For each steady state, we start with a guess for the house price (and a guess for accidental bequests) and solve the decision rules by using value function iterations. Using these decision rules, we simulate an economy with 10,000 individuals for 3,750 periods (and discard the data on the first 750 years) and generate aggregate statistics for the economy. We find the aggregate housing demand and compare it with the housing supply. If there is excess demand (excess supply), we increase (decrease) the initial price and redo the values function iterations. We continue this procedure until the beginning house price is equal to the ending one.

Transitions: We start the economy at a steady state with Proposition 13 in the first period. We then eliminate Proposition 13 unexpectedly (in period two) and solve for the transition path to the next steady state, which we
assume to be reached in $T$ periods. We set $T = 60$, but in all experiments convergence takes fewer than 60 periods.

1. We assume a price path between the two steady states where $t = 1$ represents the steady state with Proposition 13 and $t = T$ represents the steady state without Proposition 13.

2. Solve for the optimal behavior given the price path and the conditions in the “after” equilibrium by backward recursion along the transition path, using the value function from one period as the continuation value in the previous period.

3. Aggregate the decision rules along the transition to obtain the housing demand. Check to see if there is excess demand or supply in housing for each $t$.

4. Adjust the guess for the price path accordingly and go back to step 2. Continue until the path for the house price results in housing demand to equal housing supply.