Property transfer taxes, residential mobility, and welfare

Daniel Jonas Schmidt[*]

July 2022

Abstract

In this paper, I develop an overlapping generations model to analyze the effects of property transfer taxes on homeownership, residential mobility, and welfare in the Netherlands. A revenue-neutral abolition of the 2% transfer tax increases the likelihood that homeowners sell their old house and buy a new one by about 40%. It also leads to a rise of the homeownership rate by 1-5 percentage points (depending on how revenue neutrality is achieved). Newborns prefer to live in an economy without property transfer taxes if the forgone tax revenues are replaced with higher annual property taxes, but not if revenue neutrality is achieved with higher income taxes. I also consider a partial reform that only exempts young first-time homebuyers from the transfer tax and is financed with higher annual property taxes. The resulting welfare gains are approximately one half of the welfare gains from the complete reform.

Keywords: Property transfer tax, transaction tax, stamp duty, first-time buyers, residential mobility, OLG model

[*]University of Amsterdam, Roetersstraat 11, Amsterdam, 1018WB, d.j.schmidt2@uva.nl. First draft: November 2020. I am grateful to my advisors Marcelo Pedroni and Roel Beetsma for their continued guidance and support. I would also like to thank the seminar/ conference participants at the University of Amsterdam, at the 11th European Meeting of the Urban Economics Association, and at the Echoppe Conference on The Economics of Housing and Housing Policies for useful comments and suggestions. Declaration of interest: none.

1 Introduction

A property transfer tax distorts the decision of homeowners whether to stay or to move house because it increases the cost of moving. Therefore such a tax makes it more likely that a household will stay in a house that is either too small, too big, or in an unsuitable location. For this reason, it has been suggested to replace property transfer taxes with a tax that does not penalize moving (Mirrlees et al., 2011).

Moreover, a property transfer tax does not only affect homeowners but also potential first-time buyers: For young households with little savings, a transfer tax is a bigger obstacle to homeownership than a tax which moves the tax burden to later in life. Since the homeownership rate among young adults has declined in the past decades in many developed countries (Fisher and Gervais, 2011, Cribb et al., 2018, Mabille, 2022), policy makers may consider an exemption from the transfer tax for young first-time buyers as a way to counteract this trend.

What are the effects of an abolition of the property transfer tax on homeownership, residential mobility, and welfare? How do the effects of an exemption for young first-time buyers differ from a full abolition? In this paper, I develop an overlapping generations model to answer these questions. I focus on reforms of property taxation in the owner-occupied sector and therefore hold tax rates fixed in the rental sector. Moreover, I consider both reforms that achieve revenue neutrality by raising the recurring property tax, and reforms that increase income taxes instead.

The model is calibrated to the Dutch economy. In the Netherlands, the property transfer tax for the owner-occupied sector has been decreased from 6% to 2% in 2011. Additionally, the Dutch government has created an exemption from the tax for first-time buyers below the age of 35 in January 2021. This paper contributes to the discussion in the Netherlands of whether these changes were beneficial and which further reforms of housing taxation should be implemented.

In addition, my analysis is relevant for a much wider range of countries: Most OECD countries levy a property transfer tax (Sánchez and Andrews, 2011) and the tax rates are often substantial - the median tax rate in the EU is 5% (Fritzsche and Vandrei, 2019). In Canada, the Czech Republic, and Finland exemptions for first-time buyers similar to the one in the Netherlands are in place, while Germany is considering to introduce such an exemption. Italy applies a much lower tax rate of 2% to the first purchase of a house compared to the standard tax rate of 9% (European Commission, 2022).

I follow the existing literature on incomplete markets models with housing in many modelling choices: The economy is populated by overlapping generations of households with a finite lifetime. Household size varies over the life-cycle. Household income has a deterministic life-cycle component and a stochastic component. Households consume non-durable goods and housing services and can choose between renting and buying a house. The ongoing costs of living in an owner-occupied house are lower than the rent for a house of the same size, but home buyers need to pay transaction costs. To finance home purchases, households can take out a mortgage. Moreover, households can accumulate liquid savings using a non-contingent asset.

The standard features of the model create three possible reasons to move house: First, households may want move to a house of a different size after receiving a persistent income shock. Second, households may want to trade up or down after a change in the number of household members. Third, if a maximum loan-to-income ratio restricts the size of the first house for households with high expected income growth, predictable increases in income can also make homeowners move house. As the expected income growth of households with a high education level is much higher than for those with a lower education level, I introduce two different education groups in the model. Note that all three motives listed above lead to mobility between houses of different sizes.

Since a considerable fraction of repeat homebuyers in the data barely adjust the house size, I introduce a shock to the suitability of a house that generates this behavior. House suitability measures how closely the properties of the house other than size (e.g. location) match the preferences of the current owner. In the year of the home purchase, the suitability of the house is at its maximal value but there is some chance that suitability decreases permanently in any future year.

The model of household behavior is complemented with a competitive rental sector, a government and an isoelastic housing supply. The main data source for calibration is the DNB Household Survey. Preference parameters, the properties of the suitability shock and the rent per unit of housing are chosen using a simulated method of moments approach. The calibrated model matches the changes in the homeownership rate over the life-cycle well and is able to generate a response of residential mobility to property transfer tax increases that is in line with the empirical literature. I also show that the introduction of suitability shocks improves the fit with the empirical distribution of house size adjustments.

Next, I simulate different reforms of the transfer tax and obtain three main results: First, households are better off in a stationary equilibrium without the transfer tax if the forgone revenues are replaced by a higher recurring property tax in the owner-occupied sector. In this case, the frequency at which homeowners sell their old house and buy a new one rises by 40%, but house prices, rents, and the homeownership rate barely change.

Second, more than one half of the welfare gains of the full abolition can already be achieved by an exemption for young first-time buyers that is financed by an increase of the property tax. This implies that making owner-occupied housing more accessible for young households is of similar importance as facilitating greater residential mobility among homeowners.

Third, abolishing the transfer tax or creating an exemption for first-time buyers is not beneficial if revenue neutrality is achieved by increasing the income tax. The main reason for this result is the unequal distribution of welfare gains and losses among households with different initial incomes. Moreover, house prices and rents increase substantially if there is no increase in the recurring property tax that counteracts the incentives to consume more housing services. This increase in housing costs also contributes to the overall welfare loss.

Related literature

Most of the empirical literature on property transfer taxes is concerned with the negative impact on residential mobility of homeowners ("lock-in effect"). An early example is van Ommeren and van Leuvensteijn (2005) who combine a simple structural model of mobility decisions with a competing risk model estimated on Dutch panel data. They find that a one percentage-point increase in transaction costs decreases the residential mobility of homeowners by 8% in the Netherlands. More recent studies are summarized in table 5 in the appendix. In contrast to van Ommeren and van Leuvensteijn (2005), they rely on quasi-experimental variation in tax rates to identify the effect on mobility. Six out of seven papers find statistically significant and economically important lock-in effects in the range of 7% - 15%. I will use these estimates in section 4 for model validation. Dachis et al. (2012), Besley et al. (2014), Hilber and Lyytikäinen (2017) and Eerola et al. (2019) complement their empirical analyses by simple static models with fixed house prices to obtain a rough estimate of the welfare effect of property transfer taxes. To my best knowledge, the only empirical analysis of an exemption from the property transfer tax for young first-time buyers is Silvennoinen (2021) who exploits the age eligibility threshold to study the effects of the Finnish tax exemption.

I contribute to this literature in three ways: First, a dynamic life-cycle model can help to better understand the economic mechanisms behind residential mobility, in particular the importance of changes to household income, changes in household size, and mismatch shocks. Second, I show that general equilibrium effects matter for welfare, in particular in countries with an inelastic housing supply. Third, my results emphasize the welfare benefits of a transfer tax reform for first-time buyers which are not captured by the estimated lock-in effect.

In terms of methodology, I follow the literature on incomplete markets models with an explicit role for housing. Models of this type have been used e.g. to explain the pattern of homeownership and housing consumption over the life-cycle (Yang, 2009, Attanasio et al., 2012, Bajari et al., 2013), to analyze the impact of mortgage interest deduction (Chambers et al., 2009, Sommer and Sullivan, 2018) and to investigate the origins of the housing boom and bust (Kaplan et al., 2020). In this literature, transaction costs are an important model feature because they generate the infrequent and lumpy house size adjustments observed in the data. However, most papers in this literature view transaction costs as a fixed parameter that cannot be influenced by policymakers, even though taxes constitute on average about 50% of the housing transaction costs in OECD countries (Sánchez and Andrews, 2011).

To my best knowledge, the only other papers who study the effects of property transfer taxes with a quantitative heterogeneous agents model are Kaas et al. (2020) and Cho et al. (2021). The main goal of Kaas et al. (2020) is to understand to which degree various housing policies contribute to the low homeownership rate in Germany and if they increase or decrease welfare. In one of their counterfactual experiments, Kaas et al. (2020) lower the transfer tax rate from 5.2% to the average US level of 0.3% and replace the forgone tax revenues by raising the income tax. They find that this reform increases the homeownership rate in Germany by 8 percentage points but also leads to a welfare loss of 0.5% in consumption-equivalent terms. Kaas et al. (2020) conclude that changing the German transfer tax is not desirable.

In contemporaneous work, Cho et al. (2021) analyze the welfare implications of the 4% transfer tax in Australia and consider reforms that either replace the revenues by increasing the recurring property tax or by increasing the consumption tax. Their model also features a mismatch shock that generates more owner-owner transitions. The main welfare result is that an abolition of the transfer tax leads to a welfare gain for newborn households, and that households benefit more if the reform is financed by higher recurring property taxes and not by higher consumption taxes.

This paper makes four contributions relative to Kaas et al. (2020) and Cho et al. (2021):

First, I also consider an exemption of first-time buyers from the property transfer tax. The results for this tax exemption are not only relevant for policymakers who might contemplate to introduce it but also for the welfare implications of transfer taxes in general. While most of the previous literature, including Cho et al. (2021), attributes the welfare gains from an abolition to the improved mobility of homeowners, my results suggest that first-time buyers are at least as important as repeat buyers for the overall welfare gain.

Second, this paper resolves the apparent contradiction between the welfare results in Kaas et al. (2020) and Cho et al. (2021). The models used in these two papers differ from each other in many ways, and therefore it is not clear if the different sign of the welfare effects stem from differences between the models or from the way revenue neutrality is achieved in the tax experiments. In this paper, I replace the foregone tax revenues both by increasing the recurring property tax and by increasing income taxes, and I explain why this aspect of the tax experiments is crucial for the sign of the welfare change.

Third, I find a welfare gain from the abolition of the transfer tax reform even though I make more conservative choices about the rental sector compared to Cho et al. (2021). In their model, private landlords rent out housing which leads to a drop in rents (but an increase in house prices) in response to an abolition of the transfer tax. Therefore, the poorest households automatically benefit in Cho et al. (2021) which makes it much easier to achieve an overall welfare gain. This stands in contrast to the competitive rental sector in my model which implies a constant price-to-rent ratio and, consequently, an increase in rents.

Fourth, in Kaas et al. (2020) and Cho et al. (2021) mortgages are modelled as short-term debt subject to a minimum loan-to-value ratio. In contrast, this paper treats mortgages as long-term debt contracts subject to minimum loan-to-income and loan-to-value ratios at the time of origination. This is particularly important in countries like the Netherlands where houses are often bought without any downpayment and the loan-to-income ratio is more likely to constrain the choice of the house size.

The effects of property transfer taxes can also be analyzed in search models of the housing market (Lundborg and Skedinger, 1999, Han et al., 2022). This alternative approach emphasizes the effect of changes in the transfer tax on search frictions but abstracts from the heterogeneity in age, income and wealth among households.

Structure of the paper

The paper is structured as follows: Section 2 outlines the quantitative model. Sections 3 and 4 describe the calibration of the model to the Dutch economy and the properties of the calibrated model. Section 5 simulates the abolition of the transfer tax and discusses the effects of this reform on housing decisions and welfare. The analysis is repeated for an exemption of young first-time buyers from the property transfer tax. Section 6 concludes.

2 Model

Section 2.1 describes the decision problem of a household in the model. Section 2.2 adds a competitive rental sector, a government, and housing supply to the model and defines the stationary equilibrium. For the numerical solution of the model, see appendix A.

2.1 Household decision problem

Households live J years where age is indexed by $j = 0, 1, \dots J-1$. The household works during the first J_w of its life and retires at age J_w. The number of household members per household n_j is a deterministic function of age. Households are born with an education level $e \in \{\text{low}, \text{high}\}$ that determines their expected income growth over the life-cycle.

Preferences

The expected lifetime utility of a household

$$\mathsf{E}_0\left[\sum_{j=0}^{J-1} \beta^j u(c_j, s_j; n_j) + \beta^J v(b)\right]$$

is the sum of expected utility from consumption in periods $j = 0, \dots J-1$ and the expected utility from the bequest b, discounted with discount factor β. Household consumption of non-durable goods and housing services at age j are denoted by c_j and s_j, respectively. Household consumption is transformed into the individual consumption of a household member by dividing with an equivalence scale $q(n)$: $\hat{c} = c/q(n)$, $\hat{s} = s/q(n)$.

Following Li and Yao (2007), I assume that the utility function $u(c, s; n)$ has the form

$$u(c, s; n) = q(n)\frac{\left(\hat{c}^{1-\phi}\hat{s}^{\phi}\right)^{1-\theta}}{1-\theta} = q(n)^{\theta}\frac{\left(c^{1-\phi}s^{\phi}\right)^{1-\theta}}{1-\theta} \tag{1}$$

where ϕ denotes the relative importance of housing services compared to non-durable consumption and $1/\theta$ is the intertemporal elasticity of substitution. The parameter ϕ corresponds to the optimal expenditure share on housing services if housing consumption can be adjusted frictionlessly.[1]

The functional form of the utility from bequests is taken from De Nardi (2004):

$$v(b) = \nu\frac{(b + \underline{b})^{1-\theta}}{1-\theta} \tag{2}$$

The parameter ν denotes the strength of the bequest motive relative to the utility from consumption and $\underline{b} > 0$ determines to which degree bequests are a luxury good. The introduction of a bequest motive is necessary to match the slow decline of the homeownership rate during retirement in the data. Without a bequest motive, households would liquidate their housing wealth and consume it during retirement.

[1] The Cobb-Douglas functional form of the utility implies an elasticity of intratemporal substitution between non-durable consumption and housing services of 1. Empirical evidence on the intratemporal elasticity is mixed and estimates above and below 1 are reported in the literature (Piazzesi et al., 2007, Khorunzhina, 2021).

Income

During the first J_w years of its life, each household receives an income y_j that evolves according to

$$\log y_j = \chi_j^e + \eta_j \tag{3}$$

The deterministic life-cycle component χ_j^e depends on the education level $e \in \{\text{low}, \text{high}\}$ of the household. The idiosyncratic component η_j follows a first-order Markov process with N discrete states $\{\eta^0, \ldots \eta^{N-1}\}$. For simplicity, I assume that the state vector and the transition matrix of the Markov process do not depend on the education level.

At age J_w, the household retires and receives a constant pension income for the remaining $J - J_w$ years of its life. I approximate pension income as a fixed fraction of the income just before retirement

$$y_j = w y_{J_w - 1} \tag{4}$$

where w is the replacement ratio.[2]

Net income is $y_j - T(y_{j;\text{tax}})$ where $y_{j;\text{tax}}$ is taxable income and the function $T(y_{j;\text{tax}})$ is the income tax schedule. For households without mortgage debt, taxable income is equal to gross income y_j. In the subsection on mortgages, I explain how households with mortgage debt can deduct mortgage interest payments from the income tax.

Liquid asset

Households can save in a riskless financial asset $a_j \geq 0$ that pays a real interest rate r. Unsecured borrowing is not possible.

Housing

Housing services $s_j = z_j h_j$ are proportional to the size of the house h_j. Since the houses in the model do not differ in quality, the term "size" should not be taken literally but rather understood as a composite measure of house size and quality. The proportionality factor $0 \leq z_j \leq 1$ is the suitability of the house for the current owner. The price of one unit of housing expressed in units of the non-durable consumption good is p_b.

Home buyers choose a house size h_j from the discrete set $\{h^1, \ldots, h^{N_h}\}$ and pay transaction costs proportional to the value of the house $(\kappa_b + \tau_b) p_b h_j$ where τ_b is the property transfer tax and κ_b summarizes various non-tax transaction costs such as real estate agent fees. Home buyers will pick a house that matches their preferences very closely and are hence guaranteed to enjoy suitability $z_j = 1$ during the first year in the new house.

Households that own a house h_j pay a maintenance cost $\delta p_b h_j$ and recurring property taxes $\tau_h p_b h_j$ that are proportional to the value of the house. Maintenance offsets depreciation at the rate δ completely.

[2] A better approximation of the pension system in the Netherlands could be achieved by expressing pension income as a fixed fraction of average income during the working life. However, this would require an additional state variable in the household decision problem which would increase the computational complexity substantially (Guvenen and Smith, 2014).

Starting in the year after the home purchase, there is a probability p^z that the suitability z_j of the house for the owner decreases from 1 to $\underline{z} < 1$. For simplicity, I assume that the low-suitability state $\underline{z}$ is permanent so that the only way for an affected household to get back to maximum suitability $z_j = 1$ is to move to another house. Since these suitability shocks are supposed to mainly capture work-related motives to move house, I assume that retired households are not subject to these shocks.

Homeowners can sell their house and either buy or rent a new house at the beginning of each period, after learning about their income state η_j and suitability state z_j. Selling is associated with transaction costs $\kappa_s p_b h_j$ proportional to the value of the house.

A renter who lives in a house of size h_j pays $p_r h_j$ where p_r is the rental price of one unit of housing. Moving from a rented house to another rented house is not associated with adjustment costs and therefore renters will always live in houses with suitability $z_j = 1$.

Mortgages

A household that buys a house h_j at age j can take out a mortgage to finance the home purchase. The mortgage balance m_j is restricted by the maximum loan-to-value ratio λ_h and the maximum loan-to-income ratio λ_y:

$$m_j \le \min(\lambda_h p_b h_j, \lambda_y y_j)$$

The most popular mortgage type in the Netherlands is an annuity mortgage that needs to be paid off within 30 years because it allows households to benefit most from mortgage interest deduction (Nederlandse Vereniging van Banken, 2014). However, modeling mortgages in this way would require time to maturity as an additional state variable. In order to avoid any increase in the computational burden, I assume that a mortgage needs to be repaid when the household reaches retirement age. The difference between retirement age and the average age of first-time home buyers in the data is roughly 30 years. Retirees are not allowed to take out a mortgage in the model.

The mortgage payments of an annuity mortgage are constant (in nominal terms). The first payment is due in the period after the home purchase. In appendix C, I demonstrate that the mortgage payment $g_j(m_j)$ at age j with a mortgage balance m_j can be written as

$$g_j(m_j) = \frac{i_m(1+i_m)^{J_w - j}}{(1+i_m)^{J_w - j} - 1} m_j = f_j m_j \tag{5}$$

where $i_m = (1+r_m)(1+\pi) - 1$ denotes the nominal mortgage interest rate, π is the inflation rate, r_m is the real mortgage interest rate, and f_j is the mortgage payment at age j as a fraction of the mortgage balance. The mortgage payment consists of an interest payment $i_m m_j$ which can be deducted from the income tax $y_{j,\mathsf{tax}} = y_j - i_m m_j$ and a repayment of the principal $(f_j - i_m)m_j$. The real mortgage balance at the beginning of the next year is

$$m_{j+1} = \frac{1}{1+\pi}(1 - f_j + i_m)m_j.$$

Note that one needs to use the nominal mortgage interest rate i_m to compute the mortgage interest payment, not the real mortgage interest rate r_m. Most articles on the welfare effects of mortgage interest deduction overlook this issue (e.g. Sommer and Sullivan, 2018, Karlman et al., 2021).

Initialization and bequests

All households start the life-cycle at age 0 without owning a house. The initial income state η_0 and initial financial wealth $(1+r)a_{-1}$ are drawn from a joint distribution F_0. The associated marginal distribution of the initial income state is equal to the stationary distribution of the Markov process. The initial cash-on-hand is computed as $x_0 = y_0 + (1+r)a_{-1}$.

The household dies after J years and its bequest b is the sum of the financial and housing wealth of the household at the beginning of period J. For households that own a house at the end of period $J-1$, I assume that the offspring sells the house and hence seller transaction costs are subtracted from the inherited housing wealth.

Household problem in recursive form

The value function of a household with education level e that does not own a house at the beginning of year j is denoted by $V^0_{j;e}(\eta_j, x_j)$ where η_j is the stochastic component of income and x_j is cash-on-hand. Such a household can either continue to rent or decide to buy a house:

$$V^0_{j;e}(\eta_j, x_j) = \max\{V^{\text{rent}}_{j;e}(\eta_j, x_j), V^{\text{buy}}_{j;e}(\eta_j, x_j)\} \tag{6}$$

Households that continue to rent choose non-durable consumption c_j, the size of the rented house h_j, and liquid assets a_j:

$$V^{\text{rent}}_{j;e}(\eta_j, x_j) = \max_{c_j, h_j, a_j \geq 0} u(c_j, h_j; n_j) + \beta \mathsf{E}_j[V^0_{j+1;e}(\eta_{j+1}, x_{j+1})] \text{ s.t.} \tag{7}$$

$$x_j = c_j + p_r h_j + a_j \tag{8}$$

$$x_{j+1} = (1+r)a_j + y_{j+1} - T(y_{j+1}) \tag{9}$$

where equation (8) is the budget constraint of a renter in period j and equation (9) computes cash-on-hand in the next period. The renter problem, as all other household decision problems, is subject to the income process described in equations (3) and (4).

Households that decide to buy a house in years $j = 0, \dots J_w - 2$ choose non-durable consumption c_j, the size of the house h_j, mortgage m_j, and liquid assets a_j:

$$V^{\text{buy}}_{j;e}(\eta_j, x_j) = \max_{c_j, h_j, m_j, a_j \geq 0} u(c_j, h_j; n_j) + \beta \mathsf{E}_j[V^1_{j+1;e}(h_j, m_j, \eta_{j+1}, z_{j+1}, x_{j+1})] \text{ s.t.} \tag{10}$$

$$m_j \leq \min(\lambda_h p_b h_j, \lambda_y y_j) \tag{11}$$

$$x_j = c_j + (1 + \tau_b + \kappa_b)p_b h_j - m_j + (\delta + \tau_h)p_b h_j + a_j \tag{12}$$

$$x_{j+1} = (1+r)a_j + y_{j+1} - T(y_{j+1}) \tag{13}$$

$$z_{j+1} = 1 \text{ with prob } 1 - p^z \text{ and } z_{j+1} = \underline{z} \text{ with prob } p^z \tag{14}$$

Households that buy a house at age $j = J_w - 1, \dots J - 1$ are not allowed to take out a mortgage and are not subject to suitability shocks, but otherwise the buyer problem stays the same.

The value function of a household with education level e that owns a house at the beginning of age j is denoted by $V^1_{j;e}(h_j, m_j, \eta_j, z_j, x_j)$ where h_j denotes the size of the house,

m_j denotes the mortgage balance and z_j denotes the suitability of the house. Homeowners choose between staying in the house and selling the house:

$$V^1_{j,e}(h_j, m_j, \eta_j, z_j, x_j) = \max\{V^{\text{stay}}_{j,e}(h_j, m_j, \eta_j, z_j, x_j), V^{\text{sell}}_{j,e}(h_j, m_j, \eta_j, x_j)\} \tag{15}$$

Homeowners that do not move make the mortgage payment and choose non-durable consumption and liquid assets:

$$\begin{aligned} V^{\text{stay}}_{j,e}(h_j, m_j, \eta_j, z_j, x_j) &= \max_{c_j, a_j \geq 0} u(c_j, z_j h_j; n_j) \\ &\quad + \beta \mathsf{E}_j[V^1_{j+1,e}(h_{j+1}, m_{j+1}, \eta_{j+1}, z_{j+1}, x_{j+1})] \text{ s.t.} && (16) \\ x_j &= c_j + (\delta + \tau_h) p_b h_j + f_j m_j + a_j && (17) \\ h_{j+1} &= h_j && (18) \\ m_{j+1} &= \frac{1}{1+\pi}(1 - f_j + i_m) m_j && (19) \\ x_{j+1} &= (1+r)a_j + y_{j+1} - T(y_{j+1} - i_m m_{j+1}) && (20) \\ \text{if } z_j = 1\text{: } z_{j+1} &= 1 \text{ with prob } 1 - p^z \text{ and } z_{j+1} = \underline{z} \text{ with prob } p^z && (21) \\ \text{if } z_j = \underline{z}\text{: } z_{j+1} &= \underline{z} && (22) \end{aligned}$$

For retired homeowners that do not move, the two last equations that describe the suitability process are replaced with $z_{j+1} = z_j$.

Households that decide to sell their house receive the proceeds from the home sale net of seller transactions costs $(1 - \kappa_s)p_b h_j$ and pay off the remaining mortgage debt $(1 + i_m)m_j$. After these changes to cash-on-hand have been taken into account, households that sell their house solve the same problem same problem as households that enter period j as renters:

$$\begin{aligned} V^{\text{sell}}_{j,e}(h_j, m_j, \eta_j, x_j) &= V^0_{j,e}(\eta_j, x'_j) && (23) \\ x'_j &= x_j + (1 - \kappa_s)p_b h_j - (1 + i_m)m_j && (24) \end{aligned}$$

where x'_j is cash-on-hand after the house sale and settling the mortgage debt.

The household dies at the end of period $J - 1$; therefore, it does not receive income at the beginning of period J and its financial wealth is simply $x_J = (1+r)a_{J-1}$. The terminal condition for the value functions is determined by the bequest motive:

$$\begin{aligned} V^0_{J,e}(\eta_J, x_J) &= v(x_J) && (25) \\ V^1_{J,e}(h_J, m_J = 0, \eta_J, z_J, x_J) &= v(x_J + (1 - \kappa_s)p_b h_J) && (26) \end{aligned}$$

2.2 Stationary equilibrium

The economy is populated by a unit mass of households. For each household that dies, a new household is born. With probability p^{low}, the newborn household has a low education level and hence faces an income profile χ^{low}_j. Otherwise, the newborn household has a high education level and an income profile χ^{high}_j. Consequently, there is no population growth in the stationary equilibrium and the distribution of households over ages $j = 0, \dots J - 1$ is uniform, also within each education group.

Following Kaplan et al. (2020), I assume that rental housing is supplied by a competitive rental sector. In addition to the maintenance cost $\delta p_b h$, rental companies face an operating cost proportional to the house value $\psi p_b h$ which may include taxes.[3] If the rental price p_r is higher than $(r + \delta + \psi)p_b$, rental companies will buy owner-occupied housing and turn it into rental housing until they are indifferent between investing into the financial asset with return r and rental housing. On the other hand, the rental sector will sell rental housing to prospective owner-occupiers if the rental price us lower than $(r + \delta + \psi)p_b$. Therefore the equilibrium condition for the rental market is

$$p_r = (r + \delta + \psi)p_b \tag{27}$$

Moreover, the government receives tax revenues from the income tax, the property tax, and the property transfer tax denoted by $T(p_b, \tau_b, \tau_h, \mathcal{T})$. The government uses these revenues to finance a fixed amount of government expenditures G. Housing supply $H_S(p_b) = H_S(1)p_b^{\epsilon_S}$ is assumed to be isoelastic with a constant price-elasticity ϵ_S.

To define the stationary equilibrium in the model, some additional notation is necessary: The state vector $\xi = (e, j, h, m, \eta, z, x)$ contains all individual state variables. Let $e \in E = \{\text{low}, \text{high}\}$, $j \in J = \{0, \dots J - 1\}$, $h \in H = \{0, h^1, \dots h^{N_h}\}$, $m \in M = \mathbb{R}_+$, $\eta \in N = \{\eta^0, \dots \eta^{N-1}\}$, $z \in Z = \{\underline{z}, 1\}$ and $x \in X = \mathbb{R}_+$ where $h = 0$ describes a household that does not own a house. The household state space is $\Xi = E \times J \times H \times M \times N \times Z \times X$. The probability measure $\mu(B)$ on the household state space Ξ indicates the mass of households with state vectors ξ in some subset $B \in \Xi$. Finally, the law of motion Q transforms the current probability measure μ into the probability measure in the next period $\mu' = Q(\mu)$. The law of motion is implicitly defined by the stochastic processes for income and suitability, the aging of households and the policy functions.

I denote the housing demand of a single household in state ξ as $h_D(\xi; p_b, \tau_b, \tau_h, \mathcal{T})$ where the dependence on the price of one unit of housing p_b and the tax system has been made explicit. For renters and home buyers, housing demand is given by the housing policy function. For homeowners that do not move, housing demand corresponds to the house size state variable. Aggregate demand for housing can be written as

$$H_D(p_b, \tau_b, \tau_h, \mathcal{T}) = \int h_D(\xi; p_b, \tau_b, \tau_h, \mathcal{T}) d\mu(\xi)$$

A stationary equilibrium for a given tax regime $\{\tau_b, \tau_h, \mathcal{T}\}$ is defined by prices p_b and p_r, a collection of value functions $\{V^0_{j;e}, V^1_{j;e}, V^{\text{rent}}_{j;e}, V^{\text{buy}}_{j;e}, V^{\text{stay}}_{j;e}, V^{\text{sell}}_{j;e}\}$ and policy functions for both education levels, and a probability measure μ such that

1. the policy functions are the optimal decision rules to the households' decision problem described by equations (1) - (26) for given prices p_b and p_r,

2. the housing market clears $H_D(p_b, \tau_b, \tau_h, \mathcal{T}) = H_S(p_b)$,

[3] Tax rates in the rental sector and in the owner-occupied sector differ in the Netherlands. Throughout the tax experiments, I will only change the tax rates of the property transfer tax and of the recurring property tax in the owner-occoupied sector, and not in the rental sector. Therefore, property taxation in the rental sector does not need to be modelled explicitly.

3. the rental price p_r satisfies equation (27),
4. the tax revenues from the income tax, property tax and property transfer tax are equal to government expenditures $T(p_b, \tau_b, \tau_h, T) = G$, and
5. the distribution μ is invariant with respect to the law of motion Q.

3 Calibration

In this section, I parameterize the model using data from the Netherlands during the period of 2010 - 2019. First, I assign parameter values that are either already provided by other studies or can directly be obtained from the data. In a second step, I estimate the remaining parameters using a simulated method of moments approach. Table 1 shows all assigned parameter values. The DNB Household Survey is the most important data source both for the external parameters and the targeted moments. See appendix B.1 for a description of the DNB Household Survey and for the definitions of household income and financial wealth.

Quantities of the non-durable consumption good and of housing are normalized as follows: One unit of the non-durable good corresponds to 1000€ in 2019. One unit of housing is defined such that its equilibrium price under the current tax regime is $p_b = 1$, i.e. 1000€ in 2019.

Demographics

I choose 25 as the age that corresponds to $j = 0$ because by this age most survey respondents have completed their education and entered the labor market. The statutory retirement age in the Netherlands was 65 until 2012 and has since then been increasing by a few months each year. Therefore, I set the number of years until retirement J_w to 41 which implies a retirement age of 66 in the model. Finally, I use the life expectancy of approximately 80 (depending on the birth cohort) to set the number of years until death to $J = 80 - 25 = 55$.

I choose $q(n) = \sqrt{n}$ as the equivalence scale. The square-root scale is close to the average over various widely used equivalence scales reported in Fernández-Villaverde and Krueger (2007).

The average effective household size $q(n_j) = \sqrt{n_j}$ as a function of age j is estimated from the DNB Household Survey and smoothed using a local linear regression. The resulting age profile of the effective household size in the right panel of figure 1 has a hump shape with a peak at age 40.

The fractions of households with a low education level $p^{\text{low}} = 57\%$ and a high education level $p^{\text{high}} = 1 - p^{\text{low}} = 43\%$ are also computed using survey data. If the household head has either an HBO or a WO degree (comparable to a college degree or higher in the US), the household is considered to have a high education level, while all other households are considered to have a low education level.

Parameter	Description	Value	Source
Demographics			
J_w	Number of years until retirement	41	Ret. age 66 - start age 25
J	Number of years until death	55	Life exp. 80 - start age 25
$q(n_j)$	Effective household size	See figure 1	DNB Household Survey
p^{low}	Fraction of households with low education	57%	DNB Household Survey
Preferences			
β	Discount factor	0.988	Simulated Method of Moments
ϕ	Preference for housing services	0.180	Simulated Method of Moments
$1/\theta$	Elasticity of intertemporal substitution	1/2	Standard value
ν	Strength of bequest motive	821	Simulated Method of Moments
$\underline{b}$	Extent of bequest as luxury	411	Simulated Method of Moments
Interest rates and inflation			
i	Nominal riskless interest rate	1.2%	DNB Statistics
i_m	Nominal mortgage interest rate	2.5%	DNB Statistics
π	Inflation rate	1.6%	OECD Database
Income			
χ_j^{low}, χ_j^{high}	Deterministic component of log income	See figure 1	DNB Household Survey
ρ_η	Autocorrelation of stochastic component	0.97	DNB Household Survey
σ_ϵ^2	Variance of innovations	0.012	DNB Household Survey
w	Pension replacement rate	71%	OECD Database
Housing			
δ	Depreciation rate/maintenance cost	1.5%	See main text
ψ	Operating cost of rental companies	1.44%	Simulated Method of Moments
κ_b	Buyer transaction costs	4%	Rabobank (2020)
κ_s	Seller transaction costs	2%	BLG Wonen (2020)
λ_h	Maximum loan-to-value ratio	100%	Determined by government
λ_y	Maximum loan-to-income ratio	4.0	Minister van Financiën (2020)
h^0	Minimum house size	158	DNB Household Survey
h^{N_h-1}	Maximum house size	747	DNB Household Survey
Suitability			
p^z	Probability of suitability shock	2.93%	Simulated Method of Moments
$\underline{z}$	Low-suitability state	0.821	Simulated Method of Moments
Taxes			
τ_0	Parameter of income tax schedule T	1.318	DNB Household Survey
τ_1	Parameter of income tax schedule T	0.856	DNB Household Survey
τ_b	Property transaction tax	2%	Determined by government
τ_h	Property tax	0.11%	COELO (2020)
Initialization			
F_0	Distribution of initial income and wealth	See main text	DNB Household Survey
Housing supply			
ϵ_S	Long-run price elasticity	0.2	Caldera and Johansson (2013)

Table 1: Parametrization of the baseline model.

Preferences

The inverse elasticity of substitution θ is set to 2, a common value in the literature on life-cycle models. The remaining preference parameters - the discount factor β, the preference for housing services ϕ, and the bequest motive parameters ν and $\underline{b}$ - are jointly estimated using the simulated method of moments. The key moments for the calibration of these four parameters are the median house-value-to-income ratio among homeowners and three statistics that describe wealth accumulation and inequality (see table 2 for details). The estimate $\phi = 0.180$ means that households would spend 18% of their expenditures in each period on housing if they could adjust the house size frictionlessly.

Interest rates and inflation

The nominal riskless interest rate $i = 1.2\%$ is computed as the average interest rate paid on deposits during the period 2010 - 2019 according to Statistics DNB. Similarly, the nominal mortgage interest rate $i_m = 2.5\%$ is the average interest rate on pure new residential mortgages. The inflation rate of 1.6% is taken from the OECD database.

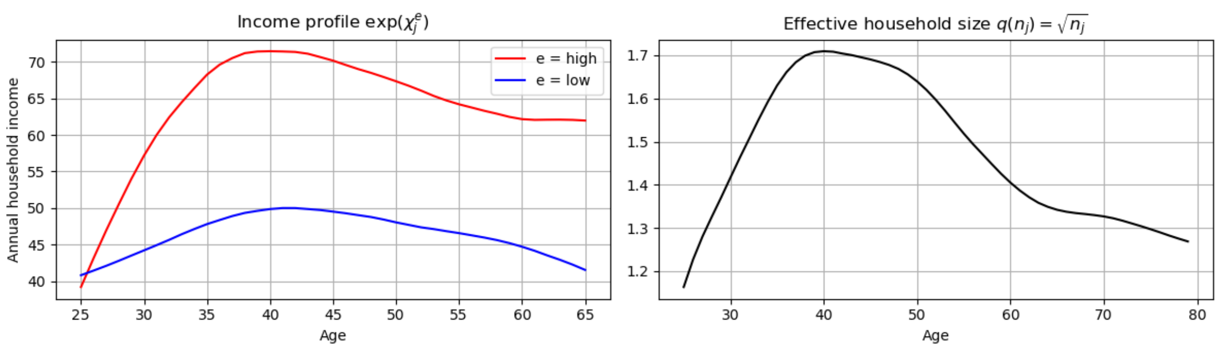


Figure 1: Age profiles for effective household size and gross income estimated from the DNB Household Survey. Income is measured in terms of units of the nondurable consumption good. One unit corresponds to 1000€ in 2019. The estimated age profiles have been smoothed using a local linear regression.

Income

For each education level, I estimate the deterministic component of log income χ_j^e using a regression of log household income on age dummies and year dummies

$$\text{log household income}_{it} = \sum_{j=0}^{40} \chi_j^e 1(\text{age}_{it} = j + 25) + \sum_{s=2010}^{2019} \alpha_s^e 1(t = s) + u_{it}$$

where i is the household index and t denotes the year. The year fixed effects are required to satisfy $\sum_s \alpha_s^e = 0$. In a second step, the estimates χ_j^e are smoothed using local linear regression. The resulting income profiles are shown in the left panel of figure 1. The growth rate of household income from age 25 to age 40 is much higher if the household head has a high education level. Household income decreases gradually after age 40 in both education groups.

In order to obtain a Markov process for the stochastic component of log income, I first estimate a persistent-transitory income process from the data. See Appendix B.2 for the details of the estimation. I find a persistence of $\rho = 0.97$ and a variance of the innovations of $\sigma^2 = 0.012$. Then, I apply the Rouwenhorst method to discretize this highly persistent AR(1) process with $N = 7$ grid points (Kopecky and Suen, 2010).

The gross pension replacement rate $w = 71\%$ in terms of pre-retirement earnings is taken from the OECD database.

Housing

Francke and van de Minne (2017) estimate an annual depreciation rate of roughly 1.5% for residential housing in the Netherlands during the first 20 years after construction and a depreciation rate of 1% during the first 50 years. The ECB finds a depreciation rate of 2% in the euro area (European Central Bank, 2006). I set the depreciation rate in the life-cycle model to $\delta = 1.5\%$. The operating cost of rental companies ψ is estimated using simulated method of moments with the homeownership rate as the key moment.

The non-tax transaction costs for buyers and sellers $\kappa_b = 4\%$ and $\kappa_s = 2\%$ are based on the information provided online by Dutch banks on typical real estate agent fees, notary fees, etc. in 2020 (e.g. Rabobank, 2020, BLG Wonen, 2020). Previous estimates of transaction costs in van Ommeren and van Leuvensteijn (2005) and Sánchez and Andrews (2011) are close to these values but might be outdated.

The maximum loan-to-value ratio and maximum debt-service-to-income ratio are determined by the Dutch government. The loan-to-value limit was reduced gradually from 105% in 2013 to 100% in 2018 and has stayed at $\lambda_h = 100\%$ since then. In appendix B.3, I derive a maximum loan-to-income limit of $\lambda_m = 4.0$ based on the rules for maximum debt servicing costs in 2020 stated in Minister van Financiën (2020).

For the grid of house sizes available to home buyers, I choose $h^1 = 158$ as the minimum since only 10% of the owner-occupied houses have a value lower than 158 000 € according to the 2010 - 2019 waves of the DNB Household Survey. As the maximum I choose $h^{N_h} = 747$ which corresponds to the 99th percentile of house values. In the calibrated model, I also check that the maximum house size is large enough so that no household would prefer to live in a house larger than $h = 747$. I choose $N_h = 8$ as the number of house sizes and use a grid with equi-distant points on a log scale. This implies that the house size increases by approximately 25% with each step on the grid.

Suitability

Both the probability of transitioning into the low-suitability state and its value are calibrated using the simulated method of moments. A detailed discussion of the targeted moments is deferred to the last part of this section. I find that the transition into the low-suitability state happens with a probability of $p^z = 2.93\%$ and that its value is roughly 18% lower compared to the state with maximum suitability.

Taxes

The progressive income tax is approximated by the functional form $T\left(y_{j;\text{tax}}\right) = y_{j;\text{tax}} \quad \tau_0 y_{j;\text{tax}}^{1}$ from Heathcote et al. (2017) where the parameter τ_0 governs the average tax rate and τ_1 determines the progressivity of the tax system. I estimate τ_0 and τ_1 with a linear regression of log net household income on log taxable household income using survey data. I subtract the mortgage interest payment stated in the DNB Household Survey from gross household income to compute taxable household income.

The property tax is levied by the municipalities and the tax rates vary. According to COELO (2020), the average property tax in the Netherlands is 0.11% in 2020.

Distribution of initial income and wealth

In the survey waves 2010-2019, about 12% of the households with a 25-year-old household head are homeowners. Since homeownership at age 25 should be determined endogenously in the model, I do not let these households start as homeowners but rather add their housing wealth net of mortgage debt and the hypothetical transaction costs to their financial wealth. If these households still prefer to become homeowners under the given tax regime, they can buy a house in period $j = 0$. Moreover, I treat households who state negative net financial wealth at age 25 in the survey as if they have zero financial wealth because unsecured borrowing is not allowed in the model.

I approximate the joint distribution of initial income and wealth by a mixture of a bivariate lognormal distribution and a degenerate distribution for households with zero financial wealth. The differences between the initial wealth distribution of households with high and low education are small compared to the estimation uncertainty; therefore, I do not differentiate between the education groups here. Since 29% of the households at age 25 have a net financial wealth equal to or below 0, I set the weight on the degenerate distribution to $p^0 = 0.29$. I approximate the distribution of log income conditional on zero financial wealth by a Normal distribution with mean $\mu^0_{\log y} = 3.29$ and variance $(\sigma^2)^0_{\log y} = 0.102$.

The parameters for the bivariate lognormal distribution for households with positive financial wealth are

$$\mu^1 = \begin{pmatrix} \mu^1_{\log y} \\ \mu^1_{\log a} \end{pmatrix} = \begin{pmatrix} 3.43 \\ 3.10 \end{pmatrix}, \quad \Sigma^1 = \begin{pmatrix} \Sigma^1_{\log y} & \Sigma^1_{\log y;\, \log a} \\ \Sigma^1_{\log y;\, \log a} & \Sigma^1_{\log a} \end{pmatrix} = \begin{pmatrix} 0.167 & 0.232 \\ 0.232 & 1.35 \end{pmatrix}$$

The correlation between log income and log financial wealth is 0.49. For a visualization of the distribution of initial income and wealth see figure 6 in section 5 where the size of the circles is proportional to the fraction of households with a certain income state and within a particular financial wealth bin.

Housing supply

I take the long-run price elasticity of housing supply $\epsilon_S = 0.2$ from Caldera and Johansson (2013). The Netherlands have a relatively inelastic housing supply: Out of the 21 OECD countries considered in Caldera and Johansson (2013), only Switzerland has a housing supply that is less elastic.

Since I have normalized one unit of housing such that the equilibrium price is $p_b = 1$ under the current tax regime, the housing supply at this price $H_S(1)$ is given by aggregate housing demand $H_D(1)$.

Simulated method of moments estimation

I use a simulated method of moments approach to estimate the preference parameters β, ϕ, ν and $\underline{b}$, the properties of the suitability shocks p^z and $\underline{z}$, and the operating cost of the rental companies ψ. For each free parameter, I target one moment that should be informative about the parameter value.

In order to estimate the discount factor β, I target mean household wealth divided be mean household income. Household wealth is defined as the sum of financial wealth and the value of the house net of the outstanding mortgage. For the parameter ϕ that governs the importance of housing services relative to non-durable goods in the utility function, I target the median of the house-value-to-income ratio among homeowners.

For the strength of the bequest motive ν, I target the change in median wealth during retirement (similar to Kaplan et al., 2020). Median household wealth in the data stays approximately constant during retirement which indicates a strong bequest motive. For the parameter $\underline{b}$ that governs the degree to which bequests are a luxury good, I target wealth inequality during retirement as measured by the 67-percentile of household wealth divided by the 33-percentile of household wealth.[4]

The operating cost of rental companies ψ is important for the choice between renting and buying. Therefore, I calibrate ψ with the homeownership rate of 69.7% as the targeted moment.

The frequency of suitability shocks p^z is chosen to match the rate of owner-owner transitions in the data, i.e. the probability that a homeowner sells their house and buys a new house in a given year. I only use data from survey waves 2015-2019 to estimate the owner-owner transition rate because of the reduction of the property transfer tax from 6% to 2% in 2011 and an unusually low rate of transitions after the 2008-2012 house price shock. The estimated annual transition rate in this period is 2.24%.

For the calibration of the low-suitability state $\underline{z}$, I exploit that the size of the suitability shock affects the distribution of house size changes for repeat buyers: If the suitability shock is very big (i.e. $\underline{z}$ is equal or close to zero), every affected homeowner will move out immediately. Most of these homeowners will not have a desire to change their house size. Therefore, I expect many owner-owner transitions in which the house size stays the same for big suitability shocks. On the other hand, if the suitability shock is small (i.e. $\underline{z}$ is close to 1), the benefits of moving may outweigh the costs only for households who already had some desire to trade up or down. Hence, I expect less transitions in which the house size stays the same for smaller suitability shocks and more transitions that involve one step up or down on the discrete housing ladder $\{h^1, \dots h^{N_h}\}$.

The DNB Household Survey provides data on the selling price of the old home and the buying price of the new home for homeowners that have moved recently. I use the buying price/ selling price ratio as a measure of the house size (and quality) adjustment. As for the

[4] I use the same approach as in appendix B.2 to account for heterogeneity in household size in the data for which there is no counterpart in the model.

frequency of owner-owner transitions, I only use data from the 2015-2019 survey waves. To obtain the empirical counterpart of the discrete steps on the housing ladder in the model, I sort the log price ratio observations into equally-sized bins with midpoints that correspond to the discrete steps. Following the argument above, I target the frequency of close to no house size changes (90%-112% bin) relative to the moderately large house size changes in the bins that correspond to one step up (112%-139 bin) or down (72%-90% bin).

Parameter	Targeted moment	Data	Model
β	Mean wealth/ mean income	3.46	3.33
ν	Median wealth at age 79/ median wealth at age 66	1.17	1.03
$\underline{b}$	Wealth inequality at age 79	3.16	1.99
ϕ	Median(house value/ income)	4.20	4.62
ψ	Homeownership rate	69.7%	69.2%
p_{z}	Owner-owner transition probability	2.24%	2.04%
$\underline{z}$	Frequency no house size change/ one step up or down	0.500	0.505

Table 2: Comparison of the empirical values of the targeted moments with the simulated values in the calibrated model.

The objective function for the simulated method of moments estimation is the weighted sum of the squared relative deviations of the simulated moments from the empirical moments

$$\min \sum_{i=1}^{7} w_i \left(\frac{M_i^{\text{model}}(\gamma) \quad M_i^{\text{data}}}{M_i^{\text{data}}} \right)^2$$

where γ denotes the vector of free parameters. I assign a weight of $w_i = 1$ to the three moments related to wealth accumulation and inequality, a weight of $w_i = 5$ to the homeownership rate, and a weight of $w_i = 2$ to the remaining three moments. Table 2 provides an overview of the empirical moments and the simulated moments in the baseline calibration. The fit is fairly good, with the biggest deviation occurring for the moment that measures wealth inequality during retirement.

4 Properties of the calibrated model

In this section, I check how well the model matches moments not targeted during the simulated method of moments estimation.

4.1 Homeownership

The left panel of figure 2 compares the homeownership rate over the life-cycle in the data with the simulated homeownership rates. Even though only the average over the life-cycle was targeted, the model matches the whole homeownership profile very well. Experiments with the model parameters show that transaction costs and the maximum loan-to-income ratio are most important for generating the slow increase in the homeownership rate between ages 25 and 40.

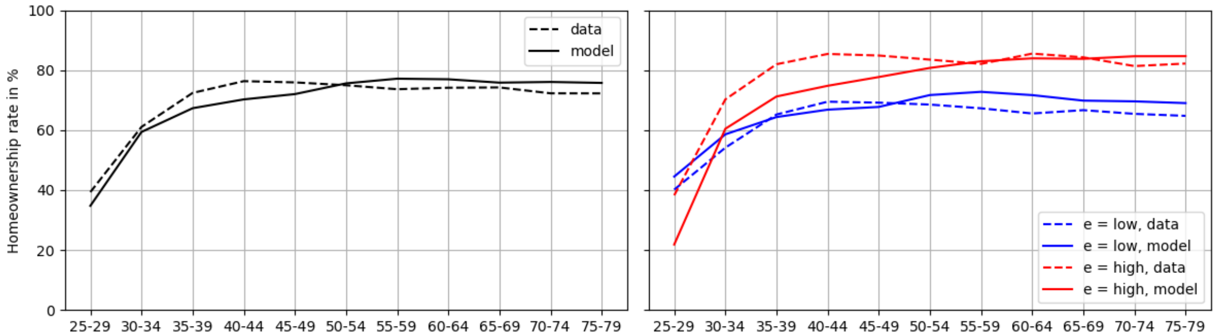


Figure 2: Homeownership rate by age in the model and in the data. The left panel shows the homeownership rate for both education groups combined while the right panel considers the two education groups separately.

Another way of validating the model is to have a closer look at differences between the two education groups because these differences were not used in the calibration. The right panel of figure 2 shows that the model matches the difference between the two education groups well for older households, but it underestimates the homeownership rate of young highly educated households.

4.2 Transition rates

During the calibration only the aggregate owner-owner transition rate was targeted. As an additional test for the model, figure 3 shows how the owner-owner transition rate and other transition rates vary over the life-cycle. As shown in the left panel, the model does not correctly reproduce the monotonous decrease of the owner-owner transition rate over the life-cycle and instead generates an inverted U shape. However, the model matches the owner-renter transition rate very well - both the average level and the variation over the life-cycle.

In order to better understand owner-owner transitions in the model and in the data, the right panel of figure 3 plots the probability that a homeowner moves up or down the housing ladder over the life-cycle. Qualitatively, the model can match the patterns in the data relatively well - for example, it correctly predicts that trading up happens more frequently early in life and that trading down becomes more common as households get older. However, the model underestimates the frequency at which households trade up early in life and overestimates the frequency at which households trade down when they are older. Combined, these two deviations from the data are responsible for the inverted U shape of the owner-owner transition rate in the left panel of figure 3.

4.3 Distribution of house size changes

This subsection focuses on the distribution of house size changes among repeat home buyers, both to validate the model and to motivate the introduction and calibration of the suitability shocks. The empirical histogram of house size changes and the one produced by the model are

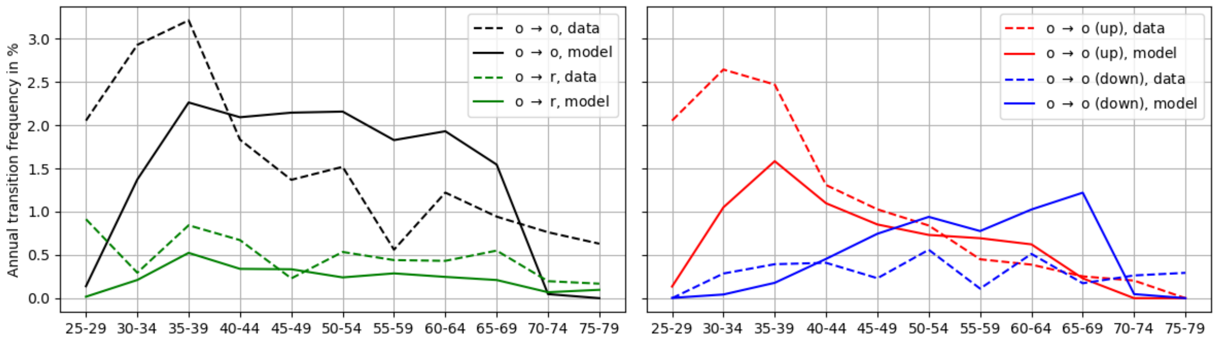


Figure 3: Transition rates between owner-occupied and rented housing by age in the model and in the data. The left panel shows the transition rate at which homeowners sell their house and buy a new one ($o \ ! \ o$) and the rate at which homeowners switch to renting ($o \ ! \ r$). The right panel separates repeat buyers depending on whether they move up or down the housing ladder.

depicted in the top left and right panel of figure 4. The simulated histogram matches the data relatively well, but generates too few large house size increases. One possible explanation is that the model does not allow for sudden changes in household size and income such as when a couple moves in together. Indeed, approximately half of the owner-owner transitions with a price ratio larger than 2 in the data happen either in the same year or in the year after the household head gets married or moves in with their partner.

The two bottom panels of figure 4 show counterfactual histograms that are generated using alternative parametrizations of the suitability shock. In the left panel, the suitability shock is turned off by setting $p^z = 0$ and, as a result, no transitions between similarly sized houses are observed in the model. Moreover, with this alternative parameterization, the owner-owner transition rate is only 1.09%, i.e. much lower than the empirical transition rate (2.24%) and the one under the standard calibration (2.04%). This clearly motivates the introduction of a shock that gives rise to the missing transitions between similarly sized houses.

In the bottom right panel of figure 4, the low-suitability state is set to $\underline{z} = 0$. Consequently, the suitability shock becomes a moving shock as in Li and Yao (2007) that forces affected households to move out. The frequency of this moving shock set to $p^z = 0.019$ so that the owner-owner transition rate is the same as in the standard calibration. The resulting histogram matches the empirical distribution of house size changes less accurately than the one generated by the standard calibration, in particular because of the high frequency of owner-owner transitions without any change in the house size. Hence, the fraction of observations in the central 1.0-bin compared to the two neighbouring bins is indeed informative about the value of the low-suitability state.

5 Tax reforms

First, I study how tax revenues and the mobility of homeowners vary with the property transfer tax. In the second subsection, I analyze a tax reform that abolishes the current

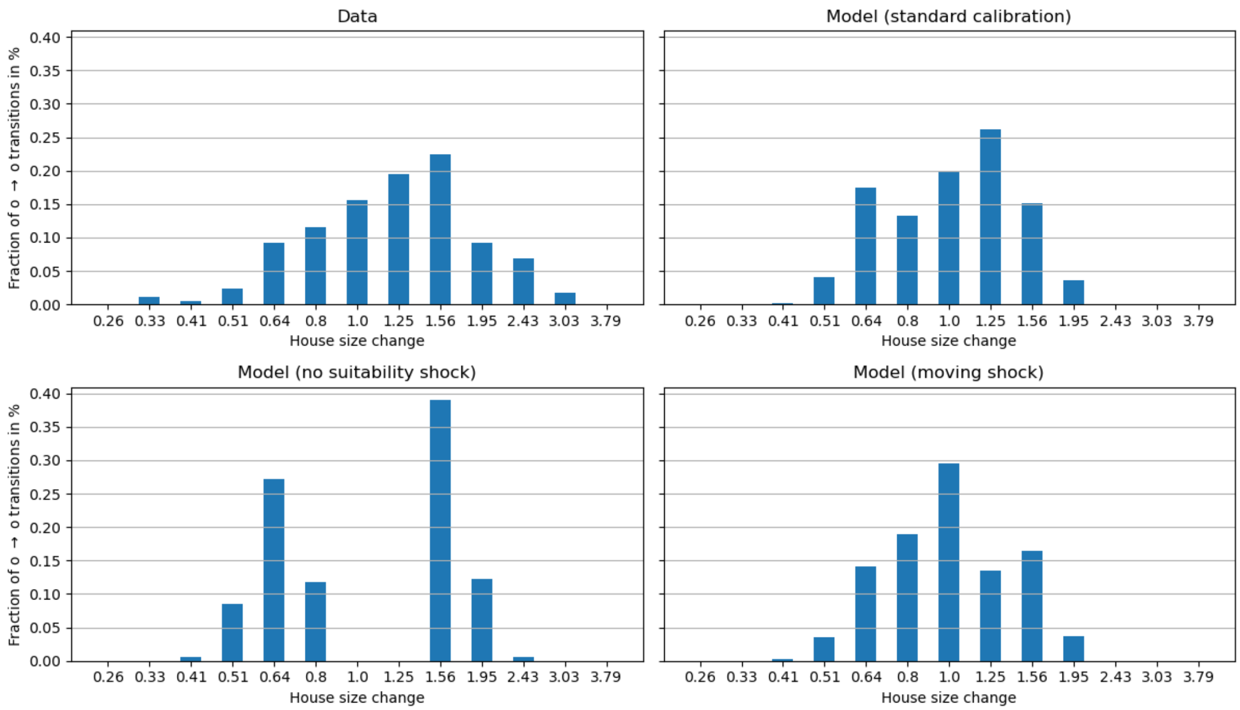


Figure 4: Top left panel: Distribution of buying price of the new house divided by selling price for the old house in the data. Top right panel: Distribution of house size changes among repeat home buyers in the model. Bottom panels: Counterfactual distributions in the model if the suitability shock is turned off (left) or replaced by a moving shock (right).

2% transfer tax for owner-occupied property in the Netherlands and increases the recurring property tax to compensate for the decrease in tax revenues. Alternatively, I also consider a reform in which revenue neutrality is achieved by raising income taxes. In the third subsection, I repeat this analysis for a tax reform that exempts young first-time home buyers from the transfer tax.

5.1 Lock-in effect and Laffer curve

To simulate the lock-in effect, I vary the rate of the property transfer tax and compute the associated mobility of homeowners in the stationary equilibrium. I do not change any features of the tax system other than the property transfer tax. The left panel of figure 5 shows that changes to the property transfer tax have a substantial impact on homeowner mobility. For example, if the current tax rate of 2% is increased to 4%, homeowner mobility decreases from 4.4% to 3.8%. This corresponds to a semi-elasticity of mobility with respect to the tax rate of 7.1% which is very close to the average estimate of the lock-in effect in the empirical literature summarized in table 5 in the appendix. The decrease in homeowner mobility with the tax rate is almost entirely due to the decrease in owner-owner transitions. The frequency of renter-owner transitions stays approximately constant as I increase the tax rate.

Furthermore, I compute annual tax revenues from the property transfer tax as I vary the

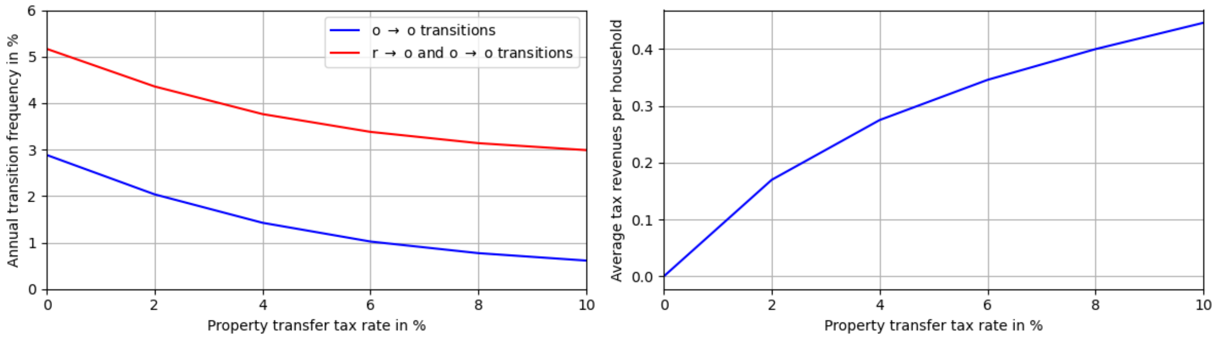


Figure 5: Effect of property transfer tax on the residential mobility of homeowners (left panel) and on tax revenues (right panel). Annual tax revenues are measured in terms of units of the non-durable consumption good. One unit corresponds to 1000€ in 2019.

tax rate and plot the resulting Laffer curve in the right panel of 5.[5] Due to the decrease in the owner-owner transition rate, tax revenues only increase by a factor of 1.6 as I double the current tax rate of 2%.

I repeat the computation of the simulated lock-in effect for a model with a moving shock as in Li and Yao (2007) instead of suitability shocks. The frequency of the moving shock is set to $p^z = 0.019$ such that the rate of owner-owner transitions is the same as with the baseline calibration. The simulated lock-in effect is only 2.6%, i.e. less than one half of the effect found with the suitability shock calibration and far outside the range of values typically found in the empirical literature. Consequently, a model with a moving shock instead of a suitability shock underestimates the effect of changes to the transfer tax.

5.2 Abolition of the property transfer tax

Table 3 presents the main results for the abolition of the 2% transfer tax in the owner-occupied sector. In order to disentangle the direct effect of the tax reform from the indirect effects via changes in house prices and rents, columns 3 and 5 keeps house prices and rents fixed, while columns 4 and 6 let them adjust to their new equilibrium levels. See appendix A.5 for information on how I compute the equilibrium house price and the change of either the recurring property tax or the income tax system that makes the reform revenue neutral.

As shown in table 3, the government needs to raise the recurring property tax from 0.11% to almost 0.20% in order to replace the foregone revenues from the transfer tax. Alternatively, it can also change the income tax parameter τ_0 so that the revenues from the income tax increase by approximately 1%.[6] The rise in house prices and rents is more muted when property taxes are increased to achieve revenue-neutrality because this change in the tax system partly offsets the incentive to consume more housing services after the abolition

[5]Changes to the transfer tax rate also affect tax revenues from the property tax and the mortgage interest deducted from the income tax via the effect on homeownership and house sizes. However, the changes in property tax revenues and income tax revenues are small and partially cancel each other out. Therefore, I ignore the impact of the transfer tax rate on other tax revenues in figure 5.

[6]The exact revenue-neutral tax rates depend on whether house prices and rents are held fixed or not. However, the differences are very small and only become apparent when more decimal places are reported.

Revenue neutrality	Baseline	Complete abolition of transfer tax $\tau_b = 2\%$				
		No	Increase property tax		Increase income tax	
Property tax rate τ_h	0.110%	0.110%	0.196%	0.196%	0.110%	0.110%
Income tax parameter τ_0	1.3178	1.3178	1.3178	1.3178	1.3108	1.3108
Change income tax revenues	-	-	-	-	1.1%	1.1%
House price change Δp	-	1.5%	-	0.2%	-	1.2%
o ! o transition rate	2.04%	2.89%	2.79%	2.79%	2.89%	2.89%
Homeownership rate	69.2%	73.9%	70.4%	70.3%	73.9%	73.9%
Welfare change	-	0.218%	0.095%	0.060%	-0.133%	-0.388%
	-	4400e	1900e	1200e	-2700e	-7800e

Table 3: Main results for the abolition of the property transfer tax. Column 1 describes the stationary equilibrium with the 2% transfer tax still in place. In column 2, the transfer tax is abolished but the forgone revenues are not replaced. In columns 3 and 4 revenue neutrality is achieved by increasing the (recurring) property tax, in columns 5 and 6 by increasing the income tax. House prices and rents are hold fixed in columns 2 and 4. Income taxes are described by the function $T(y_{j;\text{tax}}) = y_{j;\text{tax}} \quad \tau_0 y_{j;\text{tax}}^{1}$ so that a lower value of τ_0 implies a higher tax level.

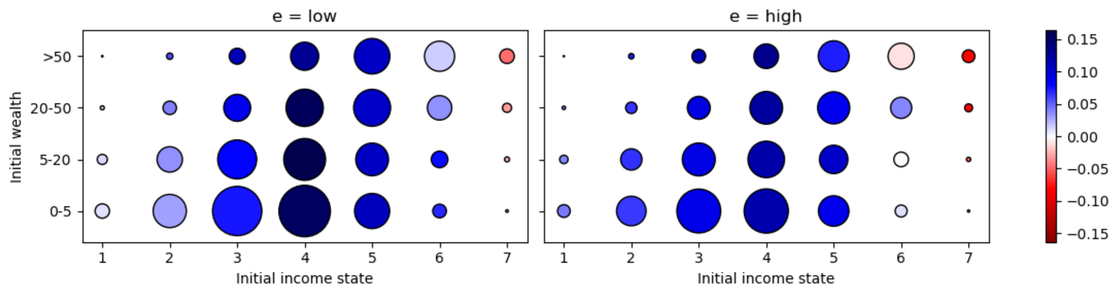
of the transfer tax. A higher income tax level, on the other hand, does not curb the increase in housing demand as much.

The owner-owner transition rate increases by about 40% regardless of whether and how revenue neutrality is achieved. The homeownership rate increases by almost 5 percentage points if income taxes are raised or foregone revenues are not replaced. If revenue neutrality is achieved by raising the property tax rate, the increase is only 1 percentage point because the higher property tax partially offsets the additional incentive to become a homeowner due to the abolition.

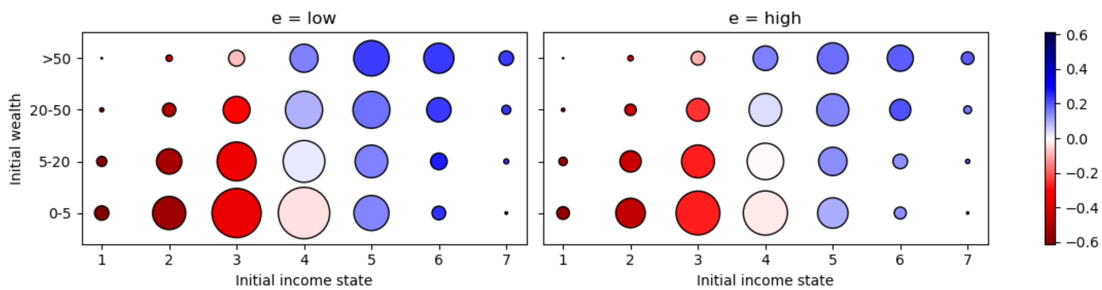
The final row in table 3 reports the effect of the different reforms on utilitarian welfare in consumption-equivalent terms. See section A.6 of the appendix for details on the computation of the welfare changes. Since an abolition of the transfer tax only directly affects households the few times they buy a new house, the associated welfare gains or losses expressed in consumption-equivalent terms are naturally quite small. For better interpretability, I also compute the present value of the additional amount of the non-durable consumption good needed for the average household.

I find a welfare gain of 0.06% or 1200e if revenue neutrality is achieved with the property tax, but a welfare loss of -0.39% or -7800e if income taxes are increased. The 1.5% increase of house prices and rents is not solely responsible for the welfare loss since the households are worse off even if prices are not allowed to adjust. For a reform that does not replace the forgone revenues I obtain a welfare gain of 0.22%.

To further investigate the welfare results, figures 6a and 6b focus on the distributional effects of the tax reforms on newborn (i.e. 25-year-old) households. Since higher housing costs decrease welfare by approximately the same amount for all households in consumption-equivalent terms, distributional effects are more clearly visible when prices are held fixed. Therefore, the two figures presented here show the case of constant house prices and rents.



(a) Revenue neutrality is achieved by increasing the property tax.



(b) Revenue neutrality is achieved by increasing the income tax. hi

Figure 6: Effect of an abolition of the property transfer tax on the welfare of newborn households if house prices and rents are held fixed. Welfare changes are measured as the percentage change of consumption in the stationary equilibrium with the 2% transfer tax that makes the households as well off as with the reform. Households are grouped by initial education level, income state and wealth. The size of each group is proportional to the area of the associated circle. Wealth is measured in terms of units of the nondurable consumption good. One unit corresponds to 1000e in 2019.

Figures 9a and 9b in the appendix depict the case of flexible house prices.

Figure 6a shows the distributional effects of the reform that achieves revenue neutrality via the property tax. Households with low initial income benefit much less from the reform compared to their peers in the middle of the income distribution because most of these households will remain renters during their whole life. If house prices and rents are allowed to adjust to their equilibrium levels, these households will have a small welfare loss due to slightly higher rents.

Surprisingly, it is only households in the highest income state who are worse off in the case of constant house prices. These households typically buy a big house early and remain homeowners their whole life. Due to mean reversion of the income process, they are less likely to trade up compared to households who start in the middle of the income distribution. Therefore, figure 8 in the appendix shows that the shift from a transfer tax to a recurring tax increases the overall tax burden of these households which explains the welfare loss.

Figure 6b depicts welfare changes if foregone revenues are replaced with a higher income tax. Households with little initial wealth and income are worse off with the tax reform because they pay higher income taxes but are unlikely to buy a house and, thus, unlikely to benefit from the abolition of the transfer tax. Households with high income and wealth benefit from the tax reform if house prices are not allowed to adjust. In the case of flexible house prices and rents, households with low initial income and wealth have even larger welfare losses, while households who are initially at the top of the income distribution become indifferent.

5.3 Exemption for young first-time buyers

In the second version of the tax reform, the transfer tax rate stays unchanged at 2% but first-time home buyers under the age of 35 are exempted from the tax. Since the exemption depends not only on age but also on whether the household has bought a house before, I need to modify the household decision problem. For households at age $j = 0, \dots 9$ without a house, I add a binary state variable that indicates whether the household is eligible for the exemption. The state variable is initialized at 1 and is set to 0 for households that have owned a house in the past.[7]

Revenue neutrality	Baseline	Exemption for young first-time buyers from tax $\tau_b = 2\%$ -	Increase property tax		Increase income tax	
Property tax rate τ_h	0.110%	0.143%	0.144%	0.144%	0.110%	0.110%
Income tax parameter τ_0	1.3178	1.378	1.3178	1.3178	1.3154	1.3154
Change income tax revenues	-	-	-	-	0.4%	0.4%
House price change Δp	-	0.5%	-	0.1%	-	0.4%
o ! o transition rate	2.04%	2.04%	2.03%	2.03%	2.04%	2.04%
Homeownership rate	69.2%	70.4%	69.4%	69.4%	70.4%	70.4%
Welfare change	-	0.117% 2300e	0.057% 1100e	0.043% 900e	-0.011% -200e	-0.098% -2000e

Table 4: Main results for the exemption of first-time buyers under the age of 35 from the property transfer tax. The structure of the table is analogous to table 3.

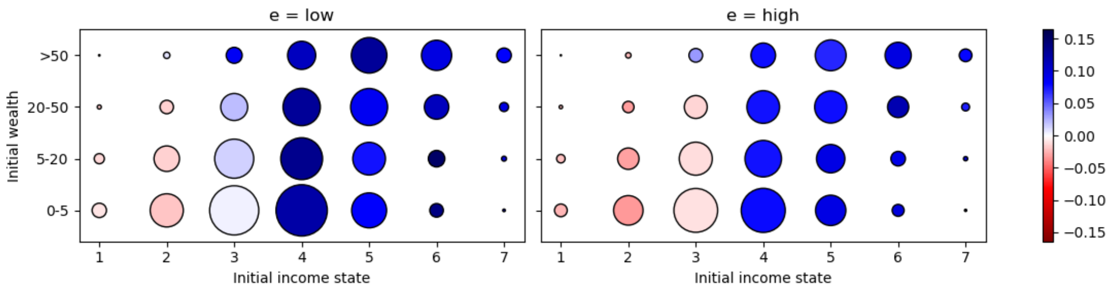
Table 4 shows the results for the exemption. Since there are still tax revenues from repeat homebuyers and first-time buyers older than 35, the increase of recurring property taxes or income taxes to the revenue-neutral level is smaller than for a complete abolition. Moreover, the house price responses in the different scenarios are approximately one third of the values reported in table 3.

The effect of the exemption on the owner-owner transition rate is negligible regardless of whether and how revenue neutrality is achieved. This is not surprising as the exemption for first-time buyers does not directly affect the decisions of potential repeat buyers in any way. The homeownership rate rises by approximately 1 percentage point if forgone revenues are not replaced or the income tax is increased and stays approximately constant if the property tax is increased. The negligible effect on the average over all ages hides more substantial changes to the homeownership rate over the life-cycle: As shown in figure 10 in the appendix,

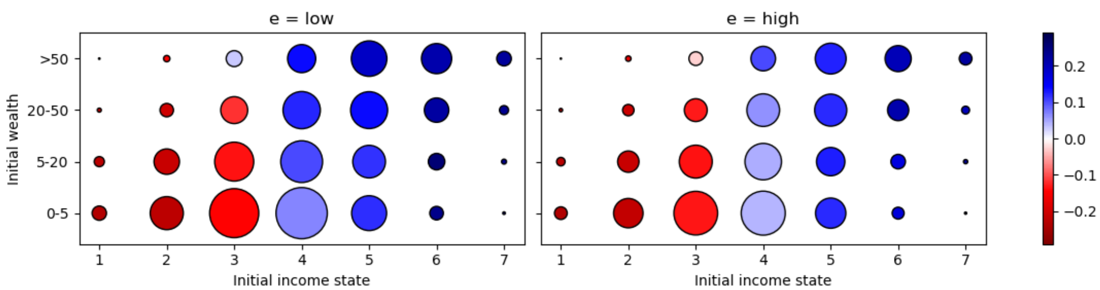
[7]Simply setting the transfer tax rate to 0% for renter-owner transitions under the age of 35 does not work because then repeat home buyers may rent for one period to use the exemption even though they are not eligible.

the homeownership rate in the 30-34 age group rises by 4%, while it decreases slightly for older households.

I find a welfare gain of 0.04% or 900e if revenue neutrality is achieved with the property tax, which corresponds to two thirds of the welfare gain associated with the complete abolition. For the case of higher income taxes, I obtain a welfare loss of -0.10% if prices are allowed to adjust. This is not only due to the higher house prices and rents since I obtain an overall welfare loss even if house prices and rents are held constant.



(a) Revenue neutrality is achieved by increasing the property tax.



(b) Revenue neutrality is achieved by increasing the income tax.

Figure 7: Effect of an exemption of young first-time buyers from the property transfer tax on the welfare of newborn households if house prices and rents are held fixed. See the caption of figure 6 for more information.

Figures 7a and 7b provide additional information on the distributional effects of the tax reforms. As in the previous subsection, house prices and rents are held constant because higher housing cost simply decrease welfare by approximately the same amount for all households and do not affect the distribution of welfare gains and losses. Figures 11a and 11b in the appendix depict the distributional effects if prices on the housing market are allowed to adjust.

Figure 7a shows the welfare changes if revenue neutrality is achieved by increasing the property tax: Households who start with in a high income state benefit from the exemption, while poorer households are slightly worse off. This happens because households in the bottom third of the income distribution typically do not buy a house before the age of 35, while the great majority of households in the top two thirds do. Moreover, some households from the bottom third will receive sufficiently large positive income shocks later in life so that it becomes optimal to buy a house. In this case, they do not profit from the exemption due to the age limit but have to pay higher property taxes, which explains the welfare loss in this group of households.

Finally, figure 7b repeats this analysis for the case of higher income taxes. The distribution of welfare losses and gains is more unequal than in figure 7a since higher income taxes shift the tax burden even more from households in the top two thirds to the bottom third of the initial income distribution.

6 Conclusion

This paper has studied the effects of different reforms of the property transfer tax. While I confirm that a property transfer tax indeed distorts mobility decisions of homeowners and should be replaced, my analysis also shows that the details of the implementation matter: It is better to replace the forgone revenues by an annual tax on owner-occupied housing than by a higher income tax. This approach makes sure that the increase of house prices and rents is muted and that the tax burden is not accidentally shifted to long-term renters who do not benefit from the tax reform.

I also find that more than half of the welfare gains of a full abolition can already be reached with an exemption for first-time buyers from the transfer tax. This finding stands in stark contrast to previous literature on property transfer taxes which has mostly attributed the welfare gains of an abolition to the increased mobility of homeowners. Therefore, future empirical and theoretical research should focus more on the effects of property transfer taxes on first-time buyers.

References

O. P. Attanasio, R. Bottazzi, H. W. Low, L. Nesheim, and M. Wakefield. Modelling the demand for housing over the life cycle. *Review of Economic Dynamics*, 15(1):1–18, 2012.

P. Bajari, P. Chan, D. Krueger, and D. Miller. A dynamic model of housing demand: Estimation and policy implications. *International Economic Review*, 54(2):409–442, 2013.

T. Besley, N. Meads, and P. Surico. The incidence of transaction taxes: Evidence from a stamp duty holiday. *Journal of Public Economics*, 119:61–70, 2014.

M. C. Best and H. J. Kleven. Housing market responses to transaction taxes: Evidence from notches and stimulus in the U.K. *The Review of Economic Studies*, 85(1):157–193, 2018.

BLG Wonen. Kosten verkoop huis, 2020. https://www.blgwonen.nl/jouw-situatie/huis-kopen/kosten-verkoop-huis.html.

A. Caldera and Å. Johansson. The price responsiveness of housing supply in oecd countries. *Journal of Housing Economics*, 22(3):231–249, 2013.

M. Chambers, C. Garriga, and D. E. Schlagenhauf. Housing policy and the progressivity of income taxation. *Journal of Monetary Economics*, 56(8):1116–1134, 2009.

Y. Cho, S. M. Li, and L. Uren. Stamping out Stamp Duty: Property or Consumption Taxes? SSRN Scholarly Paper ID 3760893, Social Science Research Network, Rochester, NY, 2021.

COELO. Atlas van de lokale lasten, 2020.

J. Cribb, A. Hood, and J. Hoyle. The decline of homeownership among young adults. Briefing note BN224, Institute for Fiscal Studies, 2018.

B. Dachis, G. Duranton, and M. A. Turner. The effects of land transfer taxes on real estate markets: evidence from a natural experiment in Toronto. *Journal of Economic Geography*, 12(2):327–354, 2012.

M. De Nardi. Wealth inequality and intergenerational links. *The Review of Economic Studies*, 71(3):743–768, 2004.

J. Druedahl. A guide on solving non-convex consumption-saving models. *Computational Economics*, 58(3):747–775, 2021.

E. Eerola, O. Harjunen, T. Lyytikäinen, and T. Saarimaa. Effects of housing transfer taxes on household mobility. CESifo Working Paper 7750, 2019.

European Central Bank. Monthly Bulletin 5, 2006. https://www.ecb.europa.eu/pub/pdf/mobu/mb200605en.pdf.

European Commission. Taxes in Europe Database v3, 2022. https://ec.europa.eu/taxation_customs/tedb/index.html.

G. Fella. A generalized endogenous grid method for non-smooth and non-concave problems. *Review of Economic Dynamics*, 17(2):329–344, 2014.

J. Fernández-Villaverde and D. Krueger. Consumption over the life cycle: Facts from consumer expenditure survey data. *The Review of Economics and Statistics*, 89(3):552–565, 2007.

J. D. Fisher and M. Gervais. Why has home ownership fallen among the young? *International Economic Review*, 52(3):883–912, 2011.

M. K. Francke and A. M. van de Minne. Land, structure and depreciation. *Real Estate Economics*, 45(2):415–451, 2017.

C. Fritzsche and L. Vandrei. The German real estate transfer tax: Evidence for single-family home transactions. *Regional Science and Urban Economics*, 74:131–143, 2019.

F. Guvenen and A. A. Smith. Inferring labor income risk and partial insurance from economic choices. *Econometrica*, 82(6):2085–2129, 2014.

L. Han, L. R. Ngai, and K. D. Sheedy. To Own or to Rent? The Effects of Transaction Taxes on Housing Markets. Technical report, 2022.

J. Heathcote, K. Storesletten, and G. L. Violante. Optimal tax progressivity: An analytical framework. *The Quarterly Journal of Economics*, 132(4):1693–1754, 2017.

C. A. L. Hilber and T. Lyytikäinen. Transfer taxes and household mobility: Distortion on the housing or labor market? *Journal of Urban Economics*, 101:57–73, 2017.

F. Iskhakov, T. H. Jørgensen, J. Rust, and B. Schjerning. The endogenous grid method for discrete-continuous dynamic choice models with (or without) taste shocks. *Quantitative Economics*, 8(2):317–365, 2017.

L. Kaas, G. Kocharkov, E. Preugschat, and N. Siassi. Low Homeownership in Germany—a Quantitative Exploration. *Journal of the European Economic Association*, 2020.

G. Kaplan, K. Mitman, and G. L. Violante. The housing boom and bust: Model meets evidence. *Journal of Political Economy*, 128(9):3285–3345, 2020.

M. Karlman, K. Kinnerud, and K. Kragh-Sørensen. Costly reversals of bad policies: the case of the mortgage interest deduction. *Review of Economic Dynamics*, 40:85–107, 2021.

N. Khorunzhina. Intratemporal nonseparability between housing and nondurable consumption: evidence from reinvestment in housing stock. *Journal of Monetary Economics*, 117: 658–670, 2021.

K. A. Kopecky and R. M. Suen. Finite state Markov-chain approximations to highly persistent processes. *Review of Economic Dynamics*, 13(3):701–714, 2010.

W. Li and R. Yao. The life-cycle effects of house price changes. *Journal of Money, Credit and Banking*, 39(6):1375–1409, 2007.

P. Lundborg and P. Skedinger. Transaction Taxes in a Search Model of the Housing Market. *Journal of Urban Economics*, 45(2):385–399, 1999.

P. Mabille. The Missing Home Buyers: Regional Heterogeneity and Credit Contractions. Technical report, 2022.

Minister van Financiën. Tijdelijke regeling hypothecair krediet, 2020. https://wetten.overheid.nl/BWBR0032503/2020-10-01.

J. Mirrlees, S. Adam, T. Besley, R. Blundell, S. Bond, R. Chote, M. Gammie, P. Johnson, G. Myles, and J. M. Poterba. *Tax By Design: The Mirrlees Review*. OUP Oxford, 2011.

Nederlandse Vereniging van Banken. The Dutch mortgage market, 2014. https://www.nvb.nl/media/2030/001298_the-dutch-mortgage-market-12082014.pdf.

M. Piazzesi, M. Schneider, and S. Tuzel. Housing, consumption and asset pricing. *Journal of Financial Economics*, 83(3):531–569, 2007.

Rabobank. Kosten koper, 2020. https://www.rabobank.nl/particulieren/hypotheek/huis-kopen/kosten/kosten-koper/.

E. Silvennoinen. Finnish first-time homebuyer's transfer tax exemption: Evidence on the effects of transfer taxes. Technical report, 2021.

J. Slemrod, C. Weber, and H. Shan. The behavioral response to housing transfer taxes: Evidence from a notched change in D.C. policy. *Journal of Urban Economics*, 100:137–153, 2017.

K. Sommer and P. Sullivan. Implications of US tax policy for house prices, rents, and homeownership. *American Economic Review*, 108(2):241–274, 2018.

A. C. Sánchez and D. Andrews. Residential mobility and public policy in OECD countries. *OECD Journal: Economic Studies*, 2011(1):1–22, 2011.

J. van Ommeren and M. van Leuvensteijn. New evidence of the effect of transaction costs on residential mobility. *Journal of Regional Science*, 45(4):681–702, 2005.

F. Yang. Consumption over the life cycle: How different is housing? *Review of Economic Dynamics*, 12(3):423–443, 2009.

A Numerical solution of the model

A.1 Household decision problem

To solve the household decision problem efficiently, I apply many computational strategies from Druedahl (2021), in particular the endogenous grid method algorithm with upper envelope described there. This algorithm builds on earlier work by Fella (2014) and Iskhakov et al. (2017) on extensions of the endogenous grid method for non-convex consumption-saving models.

In order to reduce computation time, I pre-compute the continuation values in the household decision problem

$$W^0_{j;e}(\eta_j, a_j) = \beta \mathsf{E}_j [V^0_{j+1;e}(\eta_{j+1}, x_{j+1})]$$
$$W^1_{j;e}(h_{j+1}, m_{j+1}, \eta_j, z_j, a_j) = \beta \mathsf{E}_j [V^1_{j+1;e}(h_{j+1}, m_{j+1}, \eta_{j+1}, z_{j+1}, x_{j+1})]$$

which I will refer to as the post-decision value functions in the following. I also pre-compute the post-decision marginal value of cash which is an input of the endogenous grid method:

$$\tilde{q}^0_{j;e}(\eta_j, a_j) = \beta(1+r)\mathsf{E}_j [u^0_{c;j+1;e}(\eta_{j+1}, x_{j+1})]$$
$$\tilde{q}^1_{j;e}(h_{j+1}, m_{j+1}, \eta_j, z_j, a_j) = \beta(1+r)\mathsf{E}_j [u^1_{c;j+1;e}(h_{j+1}, m_{j+1}, \eta_{j+1}, z_{j+1}, x_{j+1})]$$

With a slight abuse of notation, $u^0_{c;j+1;e}(\eta_{j+1}, x_{j+1})$ denotes the marginal utility from nondurable consumption for a household with age $j+1$, education level e, and state variables η_{j+1} and x_{j+1} who does not own a house at the beginning of the period. For linear interpolation, I always use the negative inverse transformation of value functions $1/V$ and marginal utilities for improved accuracy and in order to avoid infinities.

The renter problem in equations (7) - (9) can be solved in two steps: First, I use the endogenous grid method with a subsequent upper envelope step from Druedahl (2021) to compute optimal consumption expenditures for each possible state. The upper envelope step is necessary because the discrete decision between continuing to rent and buying in the following period makes the renter problem non-convex. Then, I solve the static problem of allocating these expenditures between nondurable consumption and housing. See appendix A.2 for more details.

The owner problem in equations (16) - (22) can be solved using a modified version of the endogenous grid method with upper envelope. The modified algorithm allows for additional expenditures such as maintenance and mortgage costs that are a function of state variables. See appendix A.3 for a description of the algorithm.

In order to solve the buyer problem, I reduce the three dimensional optimization problem in equations (10) - (14) to a two dimensional one by using the solution to the owner problem. See appendix A.4 for details.

To use the state space more efficiently, I rewrite the household problem with the loan-to-value ratio $l_j = m_j/(p_b h_j)$ as the state variable instead of the mortgage balance m_j. As the grid for the loan-to-value ratio, I use $N_l = 10$ equally spaced points between 0 and $\lambda_h = 1$. For cash-on-hand x, I construct a nonlinear grid with $N_x = 100$ points between $x_{\text{min}} = 0$ and $x_{\text{max}} = 1500$. The grid for end-of-period assets a that is necessary for the computation of the post-decision value functions $W^0_{j;e}$ and $W^1_{j;e}$ is the same as the grid for x.

A.2 Renter problem

The renter first chooses total consumption expenditures $\tilde{e}_j = c_j + p_r h_j$

$$V^{\text{rent}}_{j,e}(\eta_j, x_j) = \max_{e_j} q(n_j) \; \frac{\tilde{u}(\tilde{e}_j)^{1}}{1 \quad \theta} + W^{0}_{j,e}(\eta_j, a_j) \text{ s.t.}$$
$$x_j = \tilde{e}_j + a_j$$

and then decides how much to spend on nondurable consumption and rented housing

$$\tilde{u}(\tilde{e}) = \max_{c,h} c^{1} \quad h \quad \text{s.t. } \tilde{e} = c + p_r h$$

where the $\tilde{u}(\tilde{e})$ is the maximized utility in the static sub-problem as a function of total expenditures. From the first-order conditions and the budget constraint I obtain optimal nondurable consumption and housing consumption as a function of total expenditures $\tilde{e}$:

$$\frac{1 \quad \phi}{\phi} \left(\frac{c}{h}\right)^{\quad 1} = \frac{1}{p_r} \Longrightarrow c(\tilde{e}) = (1 \quad \phi)\tilde{e}, \; h(\tilde{e}) = \frac{\phi \tilde{e}}{p_r}$$

The maximized utility as a function of total expenditures $\tilde{e}$ is

$$\tilde{u}(\tilde{e}) = \phi \;\; (1 \quad \phi)^{1} \quad \left(\frac{1}{p_r}\right) \;\; \tilde{e}$$

Hence, I first compute optimal expenditures in each state using the endogenous grid method with upper envelope. See section A.3 but set $f(\zeta) = 0$ and replace c by $\tilde{e}$ and $u(\;)$ by $q(n)\;\tilde{u}(\;)^{1} \quad /(1 \quad \theta)$. Then, I allocate a fraction ϕ of expenditures to housing consumption and the remaining $(1 \quad \phi)$ to nondurable consumption.

A.3 Modified endogenous grid method with an upper envelope

Consider the optimization problem

$$v(\zeta, x) = \max_{c} u(c, \zeta) + w(\zeta, a) \text{ s.t.}$$
$$x = c + f(\zeta) + a$$

where c is nondurable consumption, a denotes the end-of-period assets, x denotes cash-on-hand and ζ is a vector of states other than cash-on-hand, e.g. house size and suitability. $f(\zeta)$ denotes expenditures that are a function of these state variables (e.g. costs associated with owning a house). The utility function $u(c, \zeta)$ depends both on nondurable consumption and the vector of state variables. Assume that the post-decision value function $w(\zeta, a)$ and the post-decision marginal value of cash $\tilde{q}(\zeta, a)$ have already been computed.

Algorithm 1 computes the optimal choice of nondurable consumption using a generalized endogenous grid method with a subsequent upper envelope step. The algorithm is a modified version of algorithm 1 in Druedahl (2021) that allows for expenditures $f(\zeta) \neq 0$. The inputs are the vector of state variables ζ, the cash-on-hand grid $\{x^k\}_{k=1}^{N_x}$, and the grid for end-of-period assets $\{\bar{a}^i\}_{i=1}^{N_a}$. The algorithm returns the value function and the consumption policy function discretized on the cash-on-hand grid for the given value of the other state variables ζ. Lines 1-4 describe the standard endogenous grid method. In lines 5-6, the value function is initialized at $\quad \mathit{1}$. Lines 7-11 deal with values for cash-on-hand below the expenditures $f(\zeta)$ and lines 12-15 deal with a binding borrowing constraint. Lines 16-24 describe the upper envelope algorithm.

A.4 Buyer problem

The buyer problem can be rewritten as a two-dimensional optimization over the owner value function instead of an optimization problem with three choice variables as in equations (10) - (14):

$$
\begin{aligned}
V_j^{\mathsf{buy}}(\eta_j, x_j) &= \max_{h_j; m_j} V_j^{\mathsf{stay}}(h_j, m_j^0, \eta_j, z_j = 1, x_j^0) \text{ s.t.} \\
m_j &\quad \min(\lambda_h p_b h_j, \lambda_y y_j) \\
m_j^0 &= \frac{1+\pi}{1 \quad f_j + i_m} m_j \\
x_j^0 &= x_j \quad (1 + \kappa_b + \tau_b) p_b h_j + m_j + f_j m_j^0
\end{aligned}
$$

The buyer makes the downpayment $p_b h_j \quad m_j$ and pays the transaction cost $(\kappa_b + \tau_b) p_b h_j$. Therefore, I need to subtract these payments from cash-on-hand x_j before plugging it into the owner value function. Moreover, the buyer does not make a mortgage payment $f_j m_j$ whereas the owner needs to pay it. To use the solution of the owner problem, I therefore need to adjust both cash-on-hand x_j and the mortgage balance m_j to take these differences into account. Because $1 \quad f_j + i_m < 1 + \pi$, the maximum value for the loan-to-value ratio $l_j^0 = m_j^0/(p_b h_j)$ is larger than the maximum loan-to-value ratio λ_h and therefore I need to compute the owner problem on a grid for l_j^0 which goes beyond $\lambda_h = 1$.

To make the solution of the buyer problem more precise, I compute the value function and policy functions using modified cash-on-hand grids that have grid points precisely at cash-on-hand values at which the discrete house size policy function changes.

Algorithm 1 Modified endogenous grid method with upper envelope

Input: ζ, $\{x^k\}_{k=1}^{N_x}$, $\{\bar{a}^i\}_{i=1}^{N_a}$
Output: $\{v^k\}_{k=1}^{N_x}$, $\{c^k\}_{k=1}^{N_x}$

for $i = 1, \dots N_a$ **do**
  $\bar{w}^i = w(\zeta, \bar{a}^i)$
  $\bar{c}^i = u_c^{-1}(\tilde{q}(\zeta, \bar{a}^i), \zeta)$
  $\bar{x}^i = \bar{a}^i + \bar{c}^i + f(\zeta)$
for $k = 1, \dots N_x$ **do**
  $v^k = -\infty$
$k = 1$
while $x^k \le f(\zeta)$ and $k \le N_x$ **do**
  $c^k = 0$
  $v^k = -\infty$
  $k = k + 1$
while $x^k \le \bar{x}_1$ and $k \le N_x$ **do**
  $c^k = x^k - f(\zeta)$
  $v^k = u(c^k, \zeta) + \bar{w}_1$
  $k = k + 1$
for $i = 1, \dots N_a$ **do**
  for $k = 1, \dots N_x$ **do**
    if $x^k \in [\bar{x}^i, \bar{x}^{i+1}]$ **then**
      $\hat{c}^k = \bar{c}^i + \frac{c^{i+1} - c^i}{x^{i+1} - x^i}(x^k - \bar{x}^i)$
      $\hat{a}^k = x^k - \hat{c}^k - f(\zeta)$
      $\hat{v}^k = u(\hat{c}^k, \zeta) + \left[\bar{w}^i + \frac{w^{i+1} - w^i}{x^{i+1} - x^i}(\hat{a}^k - \bar{a}^i)\right]$
      if $\hat{v}^k > v^k$ **then**
        $v^k = \hat{v}^k$
        $c^k = \hat{c}^k$

A.5 Computation of the stationary equilibrium

To compute the stationary equilibrium, I apply the Nelder-Mead minimization algorithm to a function that quantifies the deviations from the government budget constraint and from the equilibrium on the housing market for a given house price p_b and a given tax system:

$$O(p_b, \tau_b, \tau_h, T) = \left(\frac{T(p_b, \tau_b, \tau_h, T) - G}{G}\right)^2 + \left(\frac{H_D(p_b, \tau_b, \tau_h, T) - H_S(p_b)}{H_S(p_b)}\right)^2$$

If revenue neutrality is achieved by increasing the (recurring) property tax, the Nelder-Mead algorithm is only allowed to change the house price p_b and the property tax rate τ_h. If revenue neutrality is achieved by changing the income tax system, the Nelder-Mead algorithm is only allowed to change the house price p_b and the relevant parameter of the income tax system T.

To isolate the effect on house price changes on the results, I also run an experiment in which only house prices are allowed to adjust and revenue neutrality is not achieved.

To compute the equilibrium house price in this experiment, I apply Brent's root-finding algorithm to a function that returns the excess housing demand for a given house price.

Similarly, to compute the property tax or income tax rate necessary to achieve revenue neutrality while keeping house prices fixed, I apply Brent's root-finding algorithm to a function that returns the differences between tax revenues and government spending for a given tax rate.

I use Monte Carlo simulation to compute housing demand and tax revenues for a given house price and tax system. In order to ensure quick convergence of the minimization and root-finding algorithms described above, I use the same Monte Carlo realizations for the income shocks and initial financial wealth in each iteration.

A.6 Consumption-equivalent welfare change

The notation used in section 2 is not very suitable for illustrating the computation of consumption-equivalent welfare changes in a concise way. Therefore, I describe the necessary steps in a more general setting: Let $V_j(\zeta_j)$ be the lifetime utility of a household with age j and state vector ζ_j. Let $V_j \ (\zeta_j)$ denote the lifetime utility of the same household if consumption of nondurable goods is permanently increased by a factor $(1+\Delta)$ without allowing the household to re-optimize. The value function with the permanent consumption increase can be computed as follows: First, I set $V_J \ (\zeta_J) = V_J(\zeta_J)$ because the change in nondurable consumption Δ does not affect the utility from bequests. Then, I iterate backwards

$$V_j \ (\zeta_j) = u((1+\Delta)c_j(\zeta_j), s_j(\zeta_j)) + \beta \mathsf{E}_j[V_{j+1}(\zeta_{j+1}(\zeta_j))]$$

where $c_j(\zeta_j)$ and $s_j(\zeta_j)$ are the policy functions for nondurable goods and housing services computed without the permanent consumption increase. The transition function $\zeta_{j+1}(\zeta_j)$ summarizes the policy functions and stochastic processes that determine the state variables in the next period.

Let us denote lifetime utility of a household with age 0 and state vector ζ_0 in the stationary equilibrium with the tax reform as $\hat{V}_0(\zeta_0)$. Then the consumption-equivalent welfare change of the tax reform is defined as the relative consumption change Δ that makes the newborn household indifferent between the baseline tax system and the reform:

$$V_0 \ (\zeta_0) = \hat{V}_0(\zeta_0)$$

I compute Δ using Brent's root-finding algorithm. It is also possible to find the consumption-equivalent welfare change Δ for a group of households in a certain region B of the state space. The relevant condition for the root-finding algorithm in this case is

$$\int_B V_0 \ (\zeta_0) d\mu(\zeta_0) = \int_B \hat{V}_0(\zeta_0) d\mu(\zeta_0)$$

where $\mu(\zeta_0)$ is the distribution of the state variables at time 0.

B Calibration

B.1 DNB Household Survey

The DNB Household Survey is an annual longitudinal survey of Dutch households conducted by CentERdata. Households are recruited using a random sample from the database of private postal addresses and therefore the sample of households in the survey is supposed to be representative of the Dutch population. The DNB Household Survey is a self-administered survey and is conducted online; CentERdata provides a basic computer to households that do not own one. Approximately 2000 households participate in each survey wave. The survey consists of eight modules:

- HHI: General information on the household
- WRK: Household and work
- HSE: Accommodation and mortgages
- INC: Health and income
- WTH: Assets and liabilities
- PSY: Economic and psychological concepts
- AGI: Aggregated data on income
- AGW: Aggregated data on assets, liabilities and mortgages

The HHI module contains basic information on all household members, including children, which has been provided by the household head. The questions in modules WRK, HSE, INC, WTH and PSY are presented to all household members that are at least 16 years old. The modules AGI and AGW contain derived income and wealth variables that are more convenient to work with than the raw survey answers in the INC, HSE and WTH modules. For example, income from different employers stated in the INC module is aggregated to the total labor income in the AGI module.

As my measure of gross income, I use the variable BTOT from the AGI module which does not only include gross labor income but also unemployment benefits and other social security benefits. I define net financial wealth as the sum of checking accounts, saving accounts, mutual funds, bonds and stocks minus non-mortgage debt as provided in the AGW module. Since the survey questions are about the individual income and financial wealth of each household member, I aggregate income and wealth to the household level. I define household income as the combined income of the head of household and his or her partner (if present in the household). The income of adult children is not included. An analogous definition applies to the financial wealth of the household. Unfortunately, partners often do not answer questions about income and wealth in the survey. Since I treat household income/wealth as a missing value if the income/wealth of either the household head or the partner is missing, the income and wealth data of cohabiting couples is missing much more often than the income and wealth data of household heads without a partner in the household. To deal with this problem, I re-weight the observations according to the proportion of cohabiting couples at each age in the data.[8]

The problem with missing answers of partners does not apply to all housing-related variables because the HSE module only needs to be answered by one household member. All nominal values are transformed to 2019 prices using the consumer price index for the Netherlands from the OECD database.

B.2 Estimating the income process

The data features both cohabiting couples ($n_{ij}^{\mathsf{ad}} = 2$) and households in which only the household head can contribute to household income ($n_{ij}^{\mathsf{ad}} = 1$). The age profiles of log income χ_j^{e} are computed by averaging over both types of households. I modify equation (3) in order to account for the heterogeneity in the number of household members n_{ij}^{ad} that can contribute to household income

$$y_{ij} = \frac{q(n_{ij}^{\mathsf{ad}})}{q(n_j^{\mathsf{ad}})} \exp\left(\chi_j^{\mathsf{e}} + \tilde{\eta}_{ij}\right)$$

where y_{ij} is the income of household i at age j with education level e, n_j^{ad} denotes the mean of n_{ij}^{ad} at age j, and $q(n) = \rho \overline{} n$ is the equivalence scale. Hence I can isolate the stochastic component $\tilde{\eta}_{ij}$ by subtracting $\log(q(n_{ij}^{\mathsf{ad}})/q(n_j^{\mathsf{ad}})$ and the estimated age profile for education level e from log income.

I assume that the stochastic component of log income has a persistent component η_{ij} and a transitory component ζ_{ij}:

$$\begin{aligned}
\tilde{\eta}_{ij} &= \eta_{ij} + \zeta_{ij} \\
\eta_{ij} &= \rho \;\; \eta_{i;j \;\; 1} + \epsilon_{ij}
\end{aligned}$$

where $\epsilon_{ij} \quad \mathrm{N}(0, \sigma^2)$ and $\zeta_{ij} \quad \mathrm{N}(0, \sigma^2)$. I use a method of moments approach[9] to identify the autocorrelation ρ and the variances σ^2 and σ^2:

$$\begin{aligned}
\rho \;\; &= \frac{\mathrm{Cov}(y_{ij}, y_{i;j \;\; 2})}{\mathrm{Cov}(y_{ij}, y_{i;j \;\; 1})} \\
\sigma^2 &= \mathrm{Var}(y_{ij}) \quad \frac{1}{\rho}\mathrm{Cov}(y_{ij}, y_{i;j \;\; 1}) \\
\sigma^2 &= \mathrm{Var}(y_{ij}) \quad \mathrm{Cov}(y_{ij}, y_{i;j \;\; 1}) \quad \sigma^2
\end{aligned}$$

As most of the literature on life-cycle models with housing, I do not include the transitory component ζ_{ij} in the model because it is unlikely to have a huge impact on long-term consumption commitments such as housing. Moreover, i.i.d. measurement errors might also contribute to σ^2.

[8] I have also tried imputing the income of the partner based on information from the HHI module such as age, education and labor market status. The household income profiles estimated using the imputation approach closely resemble the profiles estimated using the re-weighting approach. However, it is difficult to come up with an imputation technique that does not bias the estimation of the stochastic income process. Therefore, I decided to use re-weighting instead of imputation.

[9] A GMM approach that uses higher-order autocovariances would be preferable in theory. However, the number of households for which I observe four or more consecutive income observations is very small which is why I stick to the simpler method of moments estimation.

B.3 Computing the maximum loan-to-income ratio

The maximum debt-service-to-income ratio set by the Dutch government varies with the relevant household income and the mortgage interest rate (Minister van Financiën, 2020, Table 1). If a couple applies for a mortgage loan, only 80% of the second salary is included in the income measure relevant for mortgages as of 2020. With a mortgage interest rate of $i_m = 2.5\%$ and a relevant household income between 31 000 and 49 000 Euro, the maximum debt-service-to-income ratio is 20.5%. Assuming that the second salary is 50% of the main salary, the maximum debt-service-to-income ratio with respect to actual household income is 19.1%. I apply equation (5) and assume an annuity mortgage with a duration of 30 years in order to transform the debt-service-to-income ratio to a loan-to-income ratio:

$$\lambda_m = 0.191 \cdot \left(\frac{0.025 \cdot (1+0.025)^{30}}{(1+0.025)^{30} - 1} \right)^{-1} = 4.01$$

C Derivation of the mortgage payments

The mortgage balance of an annuity mortgage at the beginning of year j is m_j. At age J_w, the mortgage needs to be paid back completely. (To be more precise, the mortgage balance in the beginning of year J_w needs to be zero; the last payment is made at age $J_w - 1$.) The mortgage payment $g_j(m_j)$ must satisfy two conditions: The nominal mortgage payments are constant over time and the present value of mortgage payments is equal to the current mortgage balance m_j plus the mortgage interest $i_m m_j$ in the current year.

$$\begin{aligned}
(1+i_m)m_j &= \sum_{k=0}^{J_w - j - 1} \frac{g_j(m_j)}{(1+i_m)^k} \\
&= \frac{1 - \frac{1}{(1+i_m)^{J_w - j}}}{1 - \frac{1}{1+i_m}} g_j(m_j) \\
&= (1+i_m)\frac{(1+i_m)^{J_w - j} - 1}{i_m(1+i_m)^{J_w - j}} g_j(m_j)
\end{aligned}$$

Rearranging for the mortgage payment $g_j(m_j)$ yields the expression in equation (5).

D Additional figures and tables

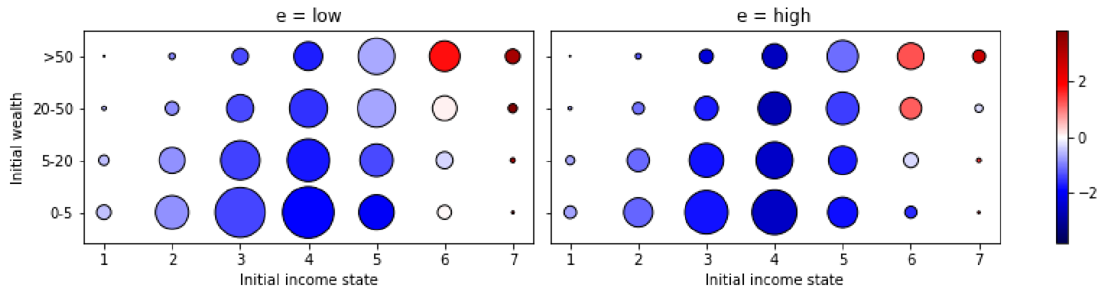
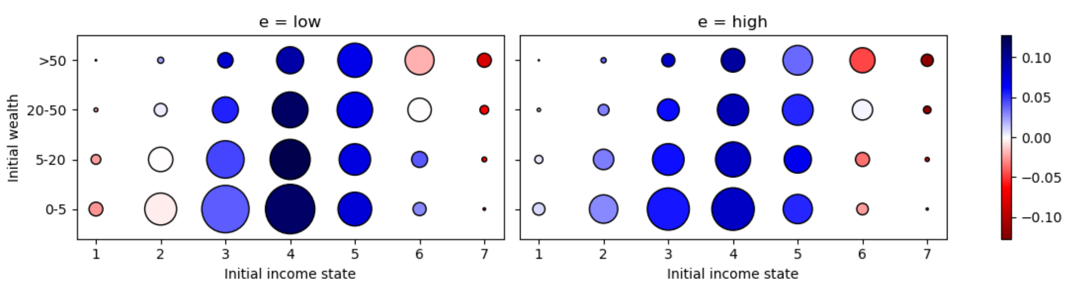
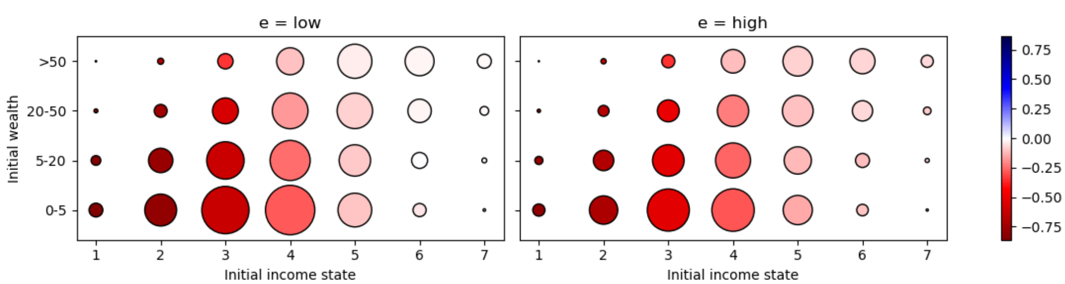


Figure 8: Change of the expected tax burden due to the abolition of the transfer tax conditional on initial income, wealth and education level. Future tax payments are discounted with the discount factor β. Revenue neutrality is achieved by rising the property tax and house prices and rents are kept fixed. Wealth and the change of the tax burden are measured in terms of units of the nondurable consumption good. One unit corresponds to 1000€ in 2019.



(a) Revenue neutrality is achieved by increasing the property tax.



(b) Revenue neutrality is achieved by increasing the income tax.

Figure 9: Effect of an abolition of the property transfer tax on the welfare of newborn households if house prices and rents are allowed to adjust.

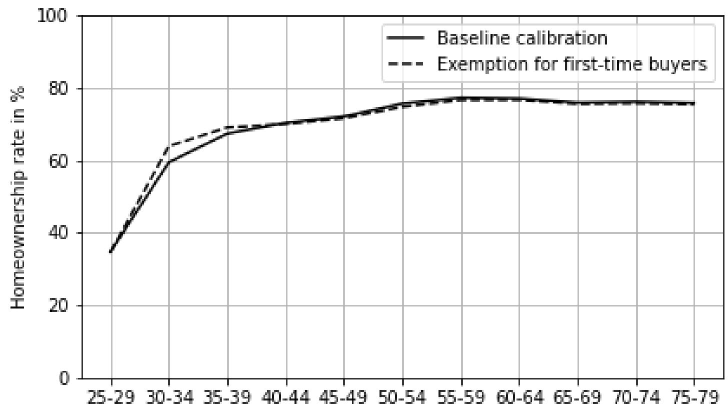
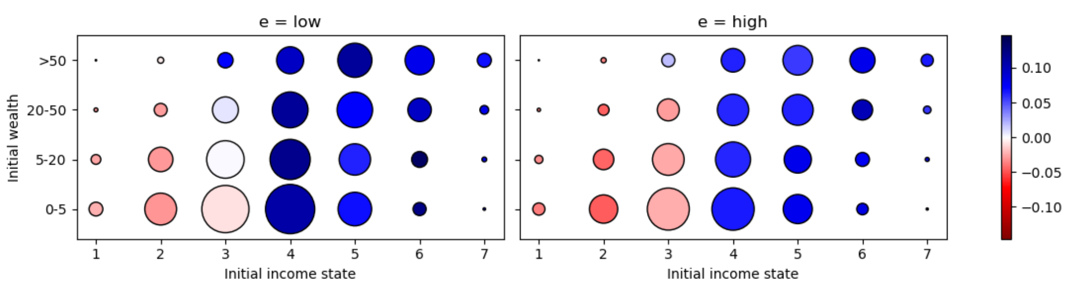
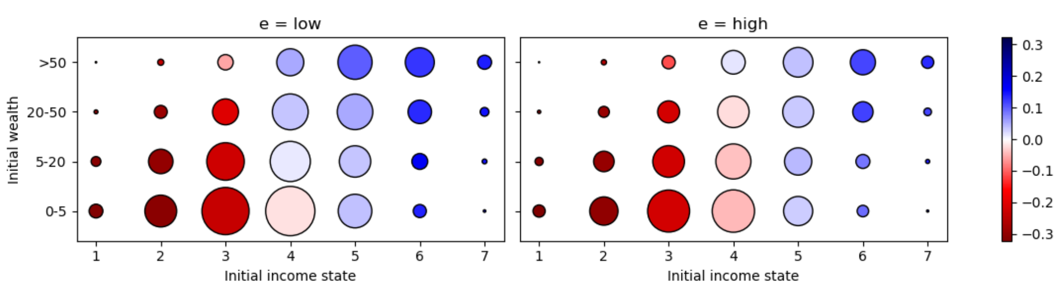


Figure 10: Age profile of the homeownership rate in the baseline calibration and with the exemption for first-time buyers under the age of 35.



(a) Revenue neutrality is achieved by increasing the property tax.



(b) Revenue neutrality is achieved by increasing the income tax.

Figure 11: Effect of an exemption of young first-time buyers from the property transfer tax on the welfare of newborn households if house prices and rents are allowed to adjust.

Table 5: Selected literature on the effect of housing transaction taxes on homeowner mobility

Article	Region	Variation in tax rates	Estimated lock-in effect
Dachis et al. (2012)	Canada, Toronto	Introduction of a housing transaction tax with an average tax rate of 1.1% in Toronto in 2001 but not in neighboring municipalities	14%
Besley et al. (2014)	UK	2008-2009 Stamp Duty Holiday: Temporary increase of the lower threshold for the tax from £125,000 to £175,000	7%, but very sensitive to specification
Best and Kleven (2018)	UK	2008-2009 Stamp Duty Holiday as in Besley et al. (2014)	11%
Hilber and Lyytikäinen (2017)	UK	Tax rate jumps from 1% to 3% at £250,000 price notch	15%
Slemrod et al. (2017)	USA, Washington D.C.	Increase of tax rate for houses with transaction price above $399,999 from 2.2% to 2.9% in 2006 (a short-lived reform in 2003 is also considered)	close to 0%, not significant
Fritzsche and Vandrei (2019)	Germany	Increases of tax rate in German states since 2006 from 3.5% to up to 6% with differences in timing and tax rates	7%
Eerola et al. (2019)	Finland	Increase of tax rate on housing co-operatives from 1.6% to 2% in 2013 while tax rate for directly-owned houses stays constant	14%

The estimated lock-in effect refers to the semi-elasticity of the residential mobility of homeowners with respect to the transaction tax rate, i.e. to the percentage decrease in mobility in response to an increase in the tax rate by one percentage point. In order to facilitate comparisons, I transform the estimates reported in the literature so that they all refer to a one percentage point increase in the tax rate.