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On Housing, Mortgages, and Taxation

Kasper Kragh-Sørensen

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Kasper Kragh-Sørensen

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Abstract

Costly reversals of bad policies: the case of the mortgage interest deduction This paper measures the welfare effects of removing the mortgage interest deduction under a variety of implementation scenarios. To this end, we build a life-cycle model with heterogeneous households calibrated to the U.S. economy, which features long-term mortgages and costly refinancing. In line with previous research, we find that most households would prefer to be born into an economy without the deductibility. However, when we incorporate transitional dynamics, less than forty percent of households are in favor of a reform and the average welfare effect is negative. This result holds under a number of removal designs.

Optimal property taxation How high should residential property taxes be? In this paper, I quantify the optimal property tax rate and how it interacts with a tax on capital income. For this purpose, I employ a general equilibrium life-cycle model with overlapping generations and incomplete markets calibrated to the U.S. economy. I find that the optimal property tax for newborns in the long run is considerably higher than its current level of one percent. In the benchmark model, the optimal property tax is about five times higher than today, and the corresponding capital income tax is reduced from 36 percent to close to zero. For current generations, however, the optimal policy is to keep the tax rates close to today’s levels. They would incur substantial welfare losses on average from an implementation of the long-run optimal policy.

Mortgage lending standards: implications for consumption dynamics In this paper, we investigate to what extent stricter mortgage lending standards affect households' ability to smooth consumption. Using a heterogeneous-household model with incomplete markets, we find that a permanently lower loan-to-value (LTV) or payment-to-income (PTI) requirement only marginally affects the aggregate consumption response to a negative wealth shock. We show that even the distribution of marginal propensities to consume across households is remarkably insensitive to these permanent policies. In contrast, households’ consumption responses can be reduced if a temporary stricter LTV or PTI requirement is implemented prior to a negative wealth shock. However, strong assumptions need to be made for temporary policies to be welfare improving.

Keywords: *Housing, life cycle, heterogeneous households, mortgage interest deduction, residential property tax, mortgage lending policies, welfare, optimal taxation.*

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Cover picture: "Soloppgang i Åsgårdstrand", Edvard Munch © Munchmuseet.
The house is located 50 meters from where I grew up.

Back-cover photo by Ellen Balke Hveem.

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To Ellen and my parents

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Abstracts

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Two out of the three chapters in this thesis are co-authored with my fellow PhD students Karin Kinnerud and Markus Karlman. The PhD would not have been half as fun without you. I believe we have truly created an environment where all questions and ideas are welcome. Still, we never naively accept unsatisfactory suggestions or explanations. Not only did we go on the job market in the same year, but we all ended up getting a position in Norway. I take this as a sign that I have been able to make a good impression of Norwegians. I am at least very excited that we will all stay in close proximity to one another.

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Kasper Kragh-Sørensen
Stockholm, Sweden
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Contents

Introduction

When I first encountered macroeconomics during my bachelor studies, the models we used were stripped-downed versions of the economies they were supposed to represent. Simple rules specified how much of total income that was consumed. During my master studies, the rules—that had appeared to come from nowhere—were now a result of deliberate choices made by a household that wanted to maximize its well-being.

The move from "rule of thumb" to a household that cares about itself was reassuring. Yet, the models still carried assumptions that were difficult to square with reality. There was only one household, i.e., no you and me. The household lived forever. Moreover, the household could insure itself against all possible uncertainties.

It was not until I embarked on my doctoral studies in Stockholm that I was formally introduced to a relatively new and important strand of modern macroeconomics, which relaxes many of the assumptions made in the models I had previously encountered. In the so-called *quantitative heterogeneous agent models*, there is no longer only one household, but many different ones as the words *heterogeneous agent* hint at. Households can have finite rather than infinite lifespans, and earnings and assets vary over the course of their lives. Households face uncertainty about future earnings and cannot perfectly insure themselves against these shocks. The gap between reality and theory narrowed significantly.

This is not to say that the models without these additional features are, by any means, outdated. In many cases, the simpler models are highly relevant and can offer valuable insights where the new models become too complex. Nevertheless, with the arrival of heterogeneous agent models, economists could offer new perspectives on old questions and ask new questions that our older models could not answer. Clearly, when there is more than one household, distributional consequences and inequality become central parts of the analysis. Thus, the relatively new strand in macroeconomics allowed the field to not only care about the "size of the cake", but also how it is divided across the population.

This thesis consists of three self-contained chapters where both aggregate and distributional effects play important roles. The chapters explore the implications of housing and mortgage market policies that are actively debated in many countries. The current debates make it clear that certain aspects of households should be part of a fruitful analysis: some households are young, while others are old; some households rent their home, while others own; and while some households are poor, others are rich. To capture the complexity of these policies, I use models that share key characteristics with those I first learned about during my PhD.

Before I turn to the full-length chapters, I provide a somewhat less technical overview of the chapters in what follows.

In Chapter 1, **Costly reversals of bad policies: the case of the mortgage interest deduction**, jointly written with Markus Karlman and Karin Kinnerud, we study how U.S. households are affected by removing the mortgage interest deduction (MID) and whether such a removal is a good idea.

The MID is a tax subsidy that has received a great deal of attention in policy discussions in the U.S. The subsidy allows homeowners to deduct mortgage interest payments from their taxable earnings. As the MID can reduce the tax payments for homeowners, it effectively lowers the cost of mortgage financing and therefore the cost of owning a house. Thus, many households are affected by the MID, not only in their decision to own as opposed to rent a home, but also when it comes to how large a house to buy. However, the subsidy is often criticized for mainly benefiting high-earners at the expense of other tax payers. Almost half of the deductions go to households in the top 20 percent of the earnings distribution, whereas households in the bottom 20 percent hardly deduct any mortgage interest payments.

To get a better understanding of who would benefit and who would lose from repealing the MID, we perform experiments in a model that is designed to represent the U.S. economy. We begin by analyzing the long-run welfare effects, i.e., we compare if households would prefer to be born into an economy with or without the MID. We find that a vast majority of households would prefer an economy where mortgage interest payments are not deductible. In an economy without the tax subsidy, households with high earnings want smaller houses. This leads to lower prices of owned and rental housing, which is particularly beneficial for low-earning households. Additionally, when the government no longer subsidizes mortgage interest payments, other taxes can be reduced. Whereas only some households benefit from the MID, all households appreciate a lower labor income tax.

Given the large welfare gains of removing the mortgage subsidy in the long run, we proceed by investigating how current households would be affected by a removal. The consequences of a removal are very different for these households. Today, many households have made long-term housing and mortgage decisions based on the premise that they can deduct their mortgage interest payments. When the subsidy is unexpectedly removed, there is a sharp drop in house prices, which hurts the existing homeowners substantially. Further, many households find themselves with too large houses and mortgages, when they can no longer deduct their interest payments. Renters, on the other hand, gain from the reform as they benefit from the fall in house prices.

We find that households are on average worse off by an immediate removal of the MID, and a majority of households are against such a policy. 70 percent of U.S. households own their home and the gains experienced by renters do not exceed the costs among homeowners. Importantly, these results also hold for alternative removal policies where the deductibility is removed gradually or when a removal is preannounced. In fact, under these alternative implementation policies, even fewer households are in favor of a removal. Although more gradual policies alleviate the losses of those hardest hit by the reform, they also make the benefits smaller. Our results thus show that the costs of reverting a bad policy can be substantial — even to the extent that it might not be worthwhile.

In Chapter 2, **Optimal property taxation**, I analyze how much we should tax residential properties.

In most countries, residential housing is either exempt from taxes or taxed quite moderately. In contrast, the income from other investments, such as the return on savings accounts, is usually taxed at high levels. Many economists argue that this tax system has unfortunate consequences for households and the economy. They argue that a low tax on housing, relative to other capital, causes households to save too much in housing at the expense of capital that could be used in firms' production. Intuitively, non-housing capital is not as lucrative when households do not receive the full return on their investment. As a result, firms have fewer machines and less equipment per worker, which reduces worker productivity. Therefore, firms are less willing to pay high wages. If firms had more capital, households' labor earnings could be increased.

However, increasing the property tax, to reduce the tax on capital income, also has its drawbacks. Higher property taxes make housing more costly. Thus, households may not afford to live in the home they would otherwise choose.

To quantify the trade-offs between a tax on housing versus a tax on capital income, I use a model of the U.S. economy. The model includes many of the salient features of the problem at hand: households can invest in housing or deposits; a firm needs capital and labor to produce goods and services; capital income and housing are taxed at different rates; and the government may reduce the tax on capital income if it increases the tax on residential property.

The results of my long-run analysis generally support the traditional view held by many economists: property taxes should be substantially increased. The optimal property tax is about five times higher than today's level of one percent. This allows the government to reduce the capital income tax from 36 percent to close to zero. Almost all households are better off. Households that are relatively unproductive benefit the most from higher wages.

Does this mean that U.S. policymakers should change today's tax rates? Not necessarily. Indeed, the average well-being of current generations is highest when the property tax is close to today's level of one percent. Whereas young households and renters would on average be better off with a higher property tax level, other households would be substantially worse off. In particular, I find that retirees and owners of smaller homes generally want to reduce the current property tax level.

Overall, the difference between optimal taxes in the long and short run provides us with a way to understand how property taxes can be beneficial for some (e.g., most future generations), but bad for others (e.g., retirees). A key implication of my work is that any policy recommendation concerning property taxation should take short-run considerations seriously.

In Chapter 3, **Mortgage lending standards: implications for consumption dynamics**, also coauthored with Markus Karlman and Karin Kinnerud, we investigate whether stricter mortgage lending standards can dampen the fall in consumption during economic downturns. Specifically, we study to what extent mortgage regulations affect how much households change their consumption, when they experience a temporary fall in wealth.

Governments in many countries have implemented stricter mortgage requirements in recent years. These policies are partly motivated by the experiences of the Great Recession, where areas with a higher growth in mortgage debt before the crisis experienced a stronger drop in consumption when the crisis hit. Regulators hope that the new mortgage requirements will make future downturns less severe. However, it is not obvious that the stricter lending standards are successful in stabilizing the economy. One way in which households can avoid a decrease in consumption is exactly by increasing their debt. By restricting the possibility to borrow, households are left with fewer options to cushion a fall in wealth. Therefore, the consumption response may be stronger than without a policy.

In this paper, we use a model to perform experiments where the loan-to-value (LTV) and the payment-to-income (PTI) requirements are made stricter. The LTV limit specifies the maximum mortgage a household can use, as a share of the house value. The PTI constraint limits the size of the mortgage in relation to earnings. In our experiments, we first study a permanent shift of the LTV limit from the current value of 0.90 to 0.70, or the PTI constraint from its current value of 0.28 to 0.18. Then, we explore the same policies, but when they are only implemented temporarily, in a year preceding an economic downturn.

Our first finding is that permanently stricter policies only marginally affect how much households reduce their consumption, when they experience an unexpected fall in wealth. Still, the policies do affect households in important ways. Fewer households own their home, they have less debt, and they save slightly more on average. Crucially, these changes in behavior are such that households' overall ability to handle economic downturns remains virtually unchanged. This result also holds for larger changes in lending standards.

Our second finding is that temporary stricter mortgage standards can successfully reduce the fall in consumption during an economic downturn. A temporary policy prevents some people from buying a house and it makes some households take up smaller mortgages. Therefore, households have more savings available when the economic downturn occurs than they would have had in the absence of the policy. As a result, they end up better prepared to handle the fall in wealth. However, we only find that a temporary policy improves the well-being of households under specific circumstances. First, the economic downturn has to be large. Second, a policymaker needs to have an informational advantage in that she can foresee the downturn, whereas households cannot.

A more general takeaway from this thesis is that modern macroeconomic models do not only make the model economy richer and more realistic. They can also be used to offer insights into political decision making. Indeed, policies are rarely enacted solely out of efficiency concerns, which is key in a one-household model. Thus, a policy that is deemed bad in models with one household may still exist because a sufficient number of people like it. Although I do not have a full account of the political process in making these decisions, I believe this thesis provides an insightful first step into thinking about why certain policies are chosen.

Chapter 1

Costly reversals of bad policies: the case of the mortgage interest deduction*

*This paper has been jointly written with Markus Karlman and Karin Kinnerud. We are grateful for helpful discussions with Tobias Broer, Jeppe Druedahl, John Hassler, Priit Jeenas, Per Krusell, Virgiliu Midrigan, Kurt Mitman, Monika Piazzesi, Kathrin Schlafmann, Martin Schneider, Roine Vestman, and seminar participants at the 2018 ECB Forum on Central Banking, the 2018 annual congress of the European Economic Association, the 2018 Nordic Summer Symposium in Macroeconomics and Finance, the 2019 ENTER Jamboree at Tilburg University, Norges Bank, the Norwegian Ministry of Finance, Stanford University, Statistics Norway, Stockholm University, the Swedish Financial Supervisory Authority, the Swedish Ministry of Finance, Sveriges Riksbank, and the 2018 Young Economists Symposium at New York University. We gratefully acknowledge funding from Handelsbanken's Research Foundations. All errors are our own.

1.1 Introduction

When the mortgage interest deductibility (MID) was passed into law through the Revenue Act of 1913, it was largely insignificant. Hardly any households paid federal income taxes, and those who did predominantly faced a marginal tax rate of only one percent (Ventry, 2010). Today, the MID has become a symbol of the "American dream" of homeownership and reduces the cost of housing for millions of Americans.

The desirability of the MID has recently been called into question. In public discussions, opponents of the MID argue that it is a costly subsidy that does little to help households into the housing market as a disproportionate share of total deductions are claimed by high earners, who would be homeowners regardless (Desmond, 2017).[1] Moreover, the results in the academic literature generally show that most American households would be better off without the MID in the long run.[2]

In this paper, we study how a removal of the MID affects households both in the short and the long run. While our analysis of long-run effects addresses the question whether households would prefer to be born into an economy with or without the MID, the short-run analysis specifically considers the welfare implications of those alive at the time of the removal. The welfare effects may be substantially different in the short run, as current households have already made long-term housing and financing decisions based on the presumption that they can deduct mortgage interest payments.

We find that although the vast majority of households would prefer to be born into a world without the MID, the implementation costs

[1]Total tax expenditures due to the MID are estimated to 63.6 billion dollars in 2017 (JCT, 2017), which is close to the entire annual spending of the Departments of Commerce, Energy, and Justice.

[2]See, e.g., Chambers et al. (2009), Floetotto et al. (2016), Gervais (2002), and Sommer and Sullivan (2018).

of a removal exceed the benefits. Less than forty percent of current households are in favor of removing the subsidy and the average welfare effect is significantly negative. Interestingly, more gradual removal policies that enable homeowners to adjust their asset holdings before the MID is removed do not increase the support for a removal. These results are robust to including the tax code changes made in the 2017 Tax Cuts and Jobs Act. Further, we cannot find a one-time transfer scheme that taxes winners and compensates losers, within the current generation, that leads to a Pareto improvement under any of the policies we consider. Our results thus show that the costs of reverting a bad policy can be substantial — even to the extent that it might not be worthwhile.

To arrive at this conclusion, we study the welfare effects of a removal of the MID through the lens of a life-cycle model with overlapping generations and incomplete markets in which house and rental prices adjust endogenously to clear the housing market. Households can borrow against their house in the form of long-term mortgages. These loans are subject to equity and payment-to-income requirements, and refinancing is costly. The tenure decision is endogenous and there are transaction costs associated with both buying and selling a house. We include the salient features of the U.S. tax code with respect to housing, namely that imputed rents are not taxed and that property taxes and mortgage interest payments are tax deductible. Furthermore, households can choose between itemized deductions and a standard deduction, where the former includes mortgage interest payments. Both deductions are subtracted from earnings that are subject to a progressive tax schedule.

We perform a series of decompositional exercises to better understand: i) why the results in the long run differ so markedly from those in the short run; and ii) why more gradual policies are ineffective in bridging this gap. A natural starting point is to understand why it is beneficial to remove the MID in the long run. We find that the positive welfare results in the long run are due to changes in several equilibrium objects. Households benefit from lower rental and house prices, a lower labor income tax rate, and higher bequests. The direct effect of removing the MID is an increase in the user cost of owning a house for households that itemize deductions. To accommodate the lower housing demand of these households, house and rental prices fall. Reduced prices make rental services more affordable and owned housing more accessible. To ensure tax neutrality, we let the labor income tax be reduced as the government no longer subsidizes mortgage financing. In addition, more bequests are distributed to households as the average net worth goes up. For most households, these positive effects outweigh the direct negative effect of removing the MID.

In our analysis of the transitional dynamics, we begin by studying the effects of an immediate removal and show that the fall in house prices, which increases welfare in the long run, decreases welfare in the short run. Lower house prices reduce housing equity, and thus the wealth of homeowners and the values of bequests. This effect hurts older homeowners in particular. Furthermore, the direct negative effect of increasing the user cost of owner-occupied housing is more prominent, especially for relatively young households that have just entered the housing market and are highly leveraged.

Given that it is beneficial for the lion's share of households to remove the MID in the long run, we explore two alternative policies that are less abrupt and give households time to adjust their asset holdings before the MID is repealed. First, we analyze the effects of linearly reducing the deductible share of mortgage interest payments over fifteen years. Second, we consider an announcement policy in which households can fully deduct their interest payments on mortgages for another fifteen years, after which no payments can be deducted. We find that the immediate policy actually results in the smallest average welfare loss among the policies and has the highest share of households who benefit from a removal. More gradual policies do successfully mitigate the welfare losses of older homeowners and households with large mortgages and high earnings. Importantly, though, these policies also significantly reduce the benefits associated with the immediate policy. Renters prefer reforms in which prices and taxes fall rapidly as they are not directly affected by an MID removal. Higher income and property taxes under more gradual policies also push a considerable share of homeowners that realize welfare gains under an immediate reform into negative welfare territory.

There is a relatively new literature that uses dynamic models with heterogeneous agents to evaluate the consequences of repealing the MID. We build on this strand of the literature, in particular on the work by Floetotto et al. (2016) and Sommer and Sullivan (2018) who both show the importance of studying heterogeneous effects in the implementation phase of housing tax reforms. We contribute to the literature in three ways.

First, contrary to the findings in Floetotto et al. (2016) and Sommer and Sullivan (2018), we find a large and negative average welfare effect of an immediate removal policy and that a majority of households are against such a reform. Although our model shares many similarities with the models in these papers, there are some key differences leading to the discrepancy in the results.[3] Of particular importance is that housing equity is less liquid in our model, due to the refinancing costs of existing mortgages. These costs are considerable, both in the data and in our model, and make it more difficult for households to cushion negative shocks.

Our analysis also differs from that of Sommer and Sullivan (2018) along other important dimensions. We use a model that realistically captures the full life cycle of households and show that the inclusion of retirees is of quantitative importance for the welfare analysis.

[3]In terms of the long-run analysis, we corroborate the important result in Sommer and Sullivan (2018) that homeownership increases when the MID is removed.

Specifically, we find that homeowners in retirement are worse off relative to the average working-age household when the MID is removed. For retirees, housing wealth constitutes a greater proportion of total resources, and they have fewer periods left to smooth the negative wealth shock caused by the house price decline. Moreover, in our analysis, households incur negative welfare effects from receiving smaller bequests along the transition due to the sudden house price drop.

Floetotto et al. (2016) study the short-run impact of an MID repeal using a life-cycle model that includes a bequest motive. However, in their analysis, mortgage interest deductions are claimed against earnings that are subject to a proportional labor income tax rate, and all homeowners are implicitly assumed to itemize deductions. In contrast, homeowners in the U.S. and in our model face a progressive labor income tax schedule, and a significant share of households with a mortgage do not itemize deductions. These features allow our model to replicate the pronounced skewness of mortgage interest deduction claims towards high-earning households as seen in the data.

The second contribution of this paper is that we consider and compare the welfare effects of alternative policies for removing the MID. We believe that our analysis of alternative policies enhances the understanding of why the MID has been challenging to repeal, and what type of trade-offs a policymaker faces. Importantly, our results suggest that natural candidates for removal policies – more gradual policies – are not necessarily preferred by households. Overall, our findings are closely related to those in Conesa and Krueger (1999), who find negative welfare effects of a transition from a pay-as-you-go social security system to a fully funded system, with the highest fraction of households in favor of an immediate reform.

Finally, we contribute by assessing how the 2017 Tax Cuts and Jobs Act affects the welfare consequences of removing the MID. The tax reform substantially reduces the number of households who itemize deductions, as the standard deduction is almost doubled and a cap on deductions for state and local income tax payments and property tax payments is introduced. Although fewer households claim mortgage interest deductions, we find that a majority of households are against a removal and the average welfare effect is still negative in the short run. The MID removal has a more moderate effect on taxes and prices, which reduces the welfare losses for homeowners, but also the welfare gains for renters.

The remainder of the paper is organized as follows. In Section 1.2 we present the model. We explore a simplified version of the model in Section 1.3 and use it to discuss the net benefit of owner-occupied housing and how it is affected by the MID. The calibration of the baseline economy is presented in Section 1.4, along with a comparison to both targeted and non-targeted data moments. Section 1.5 shows and discusses the results of the different policy experiments, while section 1.6 concludes the paper.

1.2 Model

To analyze the effects of removing the mortgage interest deductibility, we construct a life-cycle model with overlapping generations and incomplete markets. The model is in discrete time, where one model period corresponds to three years. It features three types of agents: households, rental firms, and a government. Households start their lives with different levels of net worth. Further heterogeneity arises from aging and idiosyncratic earnings shocks. Rental firms operate in a competitive market with free entry and exit, and provide rental services to households. The government taxes households and rental firms in a manner that mimics the U.S. tax system. Importantly, we include the main features of the U.S. tax code with respect to housing, namely that imputed rents are not taxed, and that property taxes and mortgage interest payments are tax deductible. Furthermore, itemized and standard tax deductions are available to households, and are deducted from earnings that are subject to a progressive tax schedule.

There are three assets in the economy: houses, mortgages, and risk-free bonds. Houses are available in discrete sizes, and there are transaction costs associated with both buying and selling a house. The stock of housing is fixed in aggregate, but flexible in its composition.[4] In equilibrium, house prices and rental prices adjust to clear the housing market. The interest rates on mortgages and bonds are exogenous and the supply of both assets is perfectly elastic.

1.2.1 Households

Households are born with initial assets as in Kaplan and Violante (2014). Over the course of the life cycle, households are hit by idiosyncratic permanent and transitory earnings shocks. A household retires with certainty after period J_{ret} and cannot live past period J. The probability of surviving between any two ages j and $j+1$ is $\phi_j \in [0,1]$, and the agents discount exponentially with a factor β. In each period, a household derives utility from a consumption good c and housing services s through a CRRA utility function with a Cobb-Douglas aggregator

$$U_j(c,s) = e_j \frac{\left(c^{\alpha} s^{1-\alpha}\right)^{1-\sigma}}{1-\sigma}, \tag{1.1}$$

where e_j is an age-dependent utility shifter that captures changes in household size over the life cycle (see, e.g., Kaplan et al. (2020)). There is also a warm-glow bequest motive similar to De Nardi (2004),

[4] The main focus of this paper is the short-run effects of a housing subsidy removal. Therefore, we find the assumption of a fixed aggregate supply of housing reasonable.

given by the bequest function

$$U^B(q') = \upsilon \frac{(q' + \bar{q})^{1-\sigma}}{1-\sigma}, \tag{1.2}$$

where υ is the weight assigned to the utility from bequests, q' is the net worth of the household, and $\bar{q}$ captures the extent to which bequests are luxury goods. The objective of the household is to maximize the expected sum of discounted lifetime utility.

A household enters each period j with bonds b, mortgage m, and house h, according to the choices made in the previous period. In the current period, earnings y are realized, the household receives bequests, and pays taxes Γ. It then chooses consumption c, housing service s, bonds b', mortgage m', and house h'. Housing services are either obtained via the agent's owned house or from a rental company. Each unit of housing costs p_h to buy and p_r to rent. An owned house of size h' produces housing services through a linear technology $s = h'$. These services have to be consumed by the owner of the house, which implies that households cannot be landlords. We model landlords implicitly through a rental market, as landlords are treated as business entities in the U.S. tax code. In addition, since landlords are treated as businesses, they are not directly affected by a removal of the mortgage interest deductibility. Households can use mortgages m', with the interest rate r^m, to finance their homeownership. Bonds b' can be purchased in any non-negative amount, earning interest $r < r^m$.

Mortgages are long-term and non-defaultable. In each period, a homeowner with a mortgage needs to adhere to an amortization schedule that specifies a minimum payment $\chi_j m$, where χ_j is defined as

$$\chi_j = \left(\sum_{k=1}^{M_j} \left[\frac{1}{(1+r_m)^k} \right] \right)^{-1}. \tag{1.3}$$

The maturity of the mortgage is given by $M_j = \min\{10, J-j\}$, which implies that the minimum payment is similar to that of an annuity mortgage with either 30 years remaining (10 model periods) or the number of years until the households dies with certainty.[5] A household that stays in a given house has the option to not follow the repayment plan by taking up a new mortgage, but then it incurs a fixed refinancing cost ς^r.

A household that takes up a new mortgage, either when it purchases a new house or refinances an existing mortgage, has to comply with two constraints. First, a loan-to-value (LTV) requirement states that a household can only use a mortgage to finance up to an exogenous share $1-\theta$ of the house value

$$m' \leq (1-\theta)p_h h'. \tag{1.4}$$

Second, a payment-to-income (PTI) constraint ensures that a household can only choose a mortgage such that the cost of housing-related payments does not exceed a fraction ψ of current permanent income z. Formally,

$$\chi_{j+1}m' + (\tau^h + \varsigma^I)p_h h' \leq \psi z, \tag{1.5}$$

where τ^h and ς^I capture property tax and home insurance payments, respectively.[6] The PTI and LTV requirements together with the refinancing cost limit the possibility to extract housing equity. Thus, instead of paying off a mortgage to increase the housing equity, liquid

[5] The 30-year mortgage contract is the most common plan in the U.S. For other ways of modeling long-term mortgages, see, e.g., Kaplan et al. (2020) or Boar et al. (2020).

[6] Mortgage payments, property taxes, and home insurance costs are three main components used by banks to assess the payment capability of mortgage applicants. The home insurance payment does not enter the household budget constraint in the model, but is included in the PTI requirement for calibration purposes, see Section 1.4.1.

bonds constitute a more suitable instrument for precautionary savings purposes. In equilibrium, some households will therefore choose to hold bonds and mortgages at the same time.

The household problem has five state variables: age j, permanent earnings z, mortgage m, house size h, and cash-on-hand x. The first two are exogenous, while the latter three are affected by a household's choices. State x is defined as

$$x \equiv y + (1+r)b - (1+r^m)m + (1-\varsigma^s)p_h h - \delta^h h + a - \Gamma, \quad (1.6)$$

where $(1-\varsigma^s)p_h h$ is the value of the house net of transaction costs.[7] The transaction cost of selling a house is modeled as a share ς^s of the house value. The maintenance cost $\delta^h h$ is paid by all homeowners, and is proportional to the size of the house. Initial assets and inheritance are captured by the term a. For a detailed description of how inheritance is modeled, see Section 1.2.3. Total tax payments are represented by Γ, and consist of five different taxes

$$\Gamma \equiv \tau^l y + I^w \tau^{ss} y + \tau^c r b + \tau^h p_h h + T(\tilde{y}). \quad (1.7)$$

Similar to the U.S. tax system, a household pays a local labor income tax τ^l, a payroll tax τ^{ss} (only paid by working-age households, represented by the dummy variable I^w), a capital income tax τ^c, a property tax on owned housing τ^h, and a federal labor income tax $T(\tilde{y})$.[8] The federal labor income tax is given by a non-linear tax and transfer system, which is a function of earnings net of deductions $\tilde{y}$. In turn, deductions depend on a household's mortgage, house value, and gross earnings. For a detailed description of the non-linear tax

[7]For computational reasons, and without loss of generality, we define cash-on-hand as including the net revenue of selling the house. Households who do not sell their house between any two periods do not incur any transaction costs.

[8]The local labor income tax is mainly included to ensure that high-earning households are more prone to itemize deductions.

and transfer system see section 1.2.3, in particular equations (1.10) and (1.11).

The household problem includes the discrete choice of whether to rent a home, buy a house, stay in an existing house but refinance the mortgage, or stay in an existing house and follow the repayment plan. Therefore, we split the household problem into these four respective cases, and solve it recursively. Let us define the expected continuation value in the next period as

$$\mathbb{E}\left[W_j(z',x',h',m',q')\right] \equiv \phi_j \mathbb{E}\left[V_{j+1}(z',x',h',m')\right] + (1-\phi_j)U^B(q').$$

If the household chooses to rent, the optimization problem is given by

$$V_j^R(z,x) = \max_{c,s,b'} U_j(c,s) + \beta\mathbb{E}\left[W_j(z',x',h',m',q')\right]$$

subject to

$$\begin{aligned} x' &= y' + (1+r)b' + a' - \Gamma' \\ q' &= b' \\ x &= c + p_r s + b' \\ s &\in S \\ c &> 0, h' = 0, b' \geq 0, m' = 0. \end{aligned}$$

The problem is characterized by the Bellman equation, the law of motion for cash-on-hand, the equation for bequests, the budget constraint where the current period cash-on-hand is given, and a number of additional constraints. In this first case, the household rents a house and can therefore not take up a mortgage, implying $h' = m' = 0$. The choice of housing service is restricted to the ordered set of discrete sizes $S = \{\underline{s}, s_2, s_3, ..., \bar{s}\}$.

If the household chooses to buy a house of a different size than what it entered the period with, such that $h' \neq h$, the problem becomes

$$V_j^B(z,x) = \max_{c,h',m',b'} U_j(c,s) + \beta\mathbb{E}\left[W_j(z',x',h',m',q')\right]$$

subject to

$$\begin{aligned}
x' &= y' + (1+r)b' + a' - \Gamma' - (1+r^m)m' + (1-\varsigma^s)p_h'h' - \delta^h h' \\
q' &= b' + p_h h' - m' \\
x &= c + (1+\varsigma^b)p_h h' + b' - m' \\
h' &\in H \\
c &> 0, s = h', b' \geq 0, m' \geq 0,
\end{aligned}$$

along with the LTV constraint (1.4), and the PTI constraint (1.5). Since the household in this case buys a house, the budget constraint allows for the use of a mortgage to finance expenditures. The parameter ς^b captures the transaction cost of buying a house, which is modeled as proportional to the house value. Moreover, the household's choice of housing is limited to a set H, which is a proper subset of S. Specifically, the smallest house size $\underline{\mathrm{h}}$ in H is larger than the smallest available size in S.[9] Above and including that lower bound, both sets are identical.

If the household decides to stay in the same house as when entering the period, such that $h' = h$, but chooses to refinance its mortgage, the problem is given by

$$V_j^{RF}(z,x,h) = \max_{c,m',b'} U_j(c,s) + \beta\mathbb{E}\left[W_j(z',x',h',m',q')\right]$$

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

subject to

$$\begin{aligned} x' &= y' + (1+r)b' + a' - \Gamma' - (1+r^m)m' + (1-\varsigma^s)p_h' h' - \delta^h h' \\ q' &= b' + p_h h' - m' \\ x &= c + b' + (1-\varsigma^s)p_h h - m' + \varsigma^r \\ c &> 0, s = h' = h, b' \geq 0, m' \geq 0, \end{aligned}$$

along with the LTV constraint (1.4), and the PTI constraint (1.5). In this case, the house size h enters as a state variable in the Bellman equation, since it directly determines the housing choice h'. Moreover, since x is defined such that it includes the value of the house when sold, the budget constraint is corrected for the agent not selling the house. This is done by adding $(1-\varsigma^s)p_h h$ to the expenditures in the budget constraint. The refinancing cost is captured by ς^r.

Finally, if the household decides to stay in its house and follow the repayment plan, the problem is

$$V_j^S(z, x, h, m) = \max_{c, m', b'} U_j(c, s) + \beta \mathbb{E}\left[W_j(z', x', h', m', q')\right]$$

subject to

$$\begin{aligned} x' &= y' + (1+r)b' + a' - \Gamma' - (1+r^m)m' + (1-\varsigma^s)p_h' h' - \delta^h h' \\ q' &= b' + p_h h' - m' \\ x &= c + b' + (1-\varsigma^s)p_h h - m' \\ m' &\leq (1+r_m)m - \chi_j m \\ c &> 0, s = h' = h, b' \geq 0, m' \geq 0. \end{aligned}$$

The mortgage level m now enters as an additional state variable as it determines the choice set for m'. Importantly, by following the repayment plan, the household is not subject to the LTV and PTI requirements.

The solution to the household problem is provided by

$$V_j(z,x,h,m) = \max\Big\{V_j^R(z,x), V_j^B(z,x), V_j^{RF}(z,x,h), V_j^S(z,x,h,m)\Big\}, \quad (1.8)$$

with the corresponding set of policy functions

$$\Big\{c_j(z,x,h,m), s_j(z,x,h,m), h_j'(z,x,h,m), m_j'(z,x,h,m), b_j'(z,x,h,m)\Big\}.$$

1.2.2 Rental market

The rental price p_r is determined in a competitive rental market. This market consists of a unit mass of homogeneous rental firms. Each firm f chooses either to buy a stock of housing h_f at price p_h per unit and rent it out to households, or to invest the value $p_h h_f$ in risk-free bonds. The present value of after-tax profits in the former case is

$$\pi_f^{Rent} = (1-\tau^c)\bigg(p_r h_f - \frac{1}{1+\tilde{r}}\Big[\delta^r + \tau^h p_h' + \Delta p_h'\Big] h_f\bigg).$$

Firm f's revenue is given by its rental income $p_r h_f$. The firm can deduct its operating expenses from these revenues before paying taxes at the rate τ^c. The operating expenses comprise a maintenance cost $\delta^r > \delta^h$ per unit of housing, a property tax on the value of the rental stock in the next period $\tau^h p_h' h_f$, and any negative price return on the rental stock $\Delta p_h' h_f$, where $\Delta p_h' \equiv p_h - p_h'$.[10] All operating expenses are discounted, as these costs are realized in the next period, at a rate given by the after-tax return on bonds $\tilde{r} \equiv (1-\tau^c)r$.

In case firm f instead invests in bonds, the present value of after-tax

[10] The assumption that $\delta^r > \delta^h$ is one common way in the literature to incorporate an advantage of owning (see, e.g., Piazzesi and Schneider (2016)). It was first introduced in Henderson and Ioannides (1983), and can be thought of as representing a moral hazard problem between owners of rental units and their tenants. An alternative approach would be to assume that owned housing units provide more housing services than rental units.

profits is given by

$$\pi_f^{Bonds} = \frac{(1-\tau^c)}{1+\tilde{r}} r p_h h_f.$$

Imposing a free entry and exit condition, such that $\pi_f^{Rent} = \pi_f^{Bonds}\ \forall f$, the equilibrium rental price is

$$p_r = \frac{1}{1+\tilde{r}}\left[\delta^r + r p_h + \tau^h p_h' + \Delta p_h'\right]. \tag{1.9}$$

Admittedly, the rental market can be modeled in other ways. This formulation captures that the return of rental investments should be closely related to the return of other assets. An additional advantage of using this approach is that it yields a tractable closed-form solution for the rental price and the net benefit of owning (see equation (1.16)), which is key to understanding how the MID affects the demand for owner-occupied housing.

1.2.3 Government

The role of the government in the model is to provide retirement benefits to households, collect bequests and distribute these to surviving households, and tax the agents in a manner that replicates the U.S. tax system. Households pay five different taxes. The local level labor income tax, the payroll tax, the capital income tax, and the property tax are modeled linearly, as shown in equation (1.7). In contrast, the federal labor income tax is given by a function that mimics the U.S. federal tax and transfer system. The labor income tax function takes earnings net of deductions $\tilde{y}$ as its argument and is assumed to be continuous and convex, following Heathcote et al. (2017). Specifically,

$$T(\tilde{y}) = \tilde{y} - \lambda \tilde{y}^{1-\tau^p}, \tag{1.10}$$

where λ governs the tax level, and τ^p determines the degree of progressivity.

The type and amounts of deductions a household takes affect taxable earnings. Before retirement, households can itemize deductions, opt for the standard deduction, or not deduct at all. Itemized deductions, including mortgage interest payments, are only permissible as long as the sum of these exceeds the standard deduction. During retirement, households can only use the standard deduction or not deduct at all. To summarize, households' taxable earnings are such that $T(\tilde{y})$ is minimized, subject to

$$\tilde{y} \in \begin{cases} \{\max(y - ID, 0), \max(y - SD, 0), y\}, & \text{if } j \leq J_{ret} \text{ and } ID > SD \\ \{\max(y - SD, 0), y\}, & \text{otherwise} \end{cases} \quad (1.11)$$

where $ID = \tau^m r^m m + \tau^h p_h h + \tau^l y$.

The max operators reflect the fact that taxable earnings must be nonnegative. SD is the common exogenous amount that can be deducted if households opt for the standard deduction, while ID is the sum of itemized deductions that includes mortgage interest payments, property tax payments, and local tax payments. These are among the most important deductions in the U.S. tax code (Lowry, 2014). The parameter τ^m is the mortgage deductibility rate in the economy and it is the parameter of interest in this paper. In line with the U.S. tax code, τ^m is set to one in the benchmark model. In other words, all mortgage interest payments are deductible from earnings when calculating taxable earnings for an itemizing household. From equations (1.6), (1.7), (1.10), and (1.11), we see that the MID reduces taxable earnings, and hence increases cash-on-hand, provided that the agent itemizes tax deductions and has a mortgage.

Rental firms pay two taxes: the property tax on their rental stock and the capital income tax on their accounting profits. In total, the government's tax revenues from households and rental firms are given by

$$TR = \sum_{j=1}^{J} \Pi_j \int_0^1 \Gamma_{ij} \, di + \int_0^1 \left(\tau^c r h_f + \tau^h p_h h_f \right) \, df, \tag{1.12}$$

where i indexes households, f indexes rental firms, Π_j is the age distribution of households, and Γ are total taxes as defined in equation (1.7). We assume that both households and rental firms are of unit measure. The government uses part of the tax revenues to finance the retirement benefits. The remaining revenues are allocated to spending that does not affect the other agents.

The government collects bequests in the form of bonds, houses, and mortgages from households who die. After the government has received these bequests, it earns the interest on bond holdings, sells the houses and incurs the transaction costs of selling, and pays off any outstanding mortgages including interest. Thus, the net amount collected from households is given by

$$BQ = \sum_{j=1}^{J} \Pi_j (1-\phi_j) \int_0^1 \left((1+r) b'_{ij} + (1-\varsigma^s) p'_h h'_{ij} - (1+r_m) m'_{ij} \right) di. \tag{1.13}$$

In the initial economy with MID, the government distributes some of these bequests to cover the initial asset holdings of newborns, whereas the remainder is, for simplicity, assumed to cover wasteful government spending. Thus, in the initial steady state, inheritance a in equation (1.6) is zero for all households of age $j > 1$.

Altering the MID is likely to affect the amount of bequests left behind. To capture the welfare effects of changes in the bequests collected, we assume that any increase or decrease in bequests is distributed to surviving households (except newborns) in proportion to a household's permanent earnings in the previous period, i.e., $a_j = \gamma z_{j-1}$ for $j > 1$. Specifically, the parameter γ is adjusted such that the amount distributed equals the change in bequests collected.

1.2.4 Equilibrium

In the equilibrium of the model, house and rental prices are endogenously determined and they adjust to ensure that the demand for housing equals the supply of housing. The model setting can be interpreted as a small open economy, where houses can only be purchased by residents and the interest rates on risk-free bonds and mortgages are taken as given.

In the initial steady state with MID, i.e., $\tau_m = 1$, we set the house price p_h equal to one. House values (price times size) are comparable to the data as the supply of housing quantity (size) is perfectly elastic and households' preferences ensure that a realistic share of expenditures is spent on housing. With the house price at hand, the rental price p_r is easily computed from equation (1.9). The rental market clears automatically as we let the rental companies cater any demand for rental units. Taking house and rental prices as given, we solve for the value and policy functions of the households and proceed by simulating the economy. The aggregate housing supply is then given by the overall demand for housing services. In the remainder of the analysis, the housing supply is fixed at this initial level, but its composition is flexible.

When we solve for the steady-state equilibrium without MID, i.e., $\tau_m = 0$, the demand for housing is affected and the house and rental prices adjust to clear the housing market. Further, we solve for the average labor income tax rate λ, such that the government's tax revenues are the same as in the initial steady state, and the bequest rate γ, such that any changes in bequests left behind are distributed to the households. Additionally, a change in the house price affects the purchasing power of a household that receives bequests. To capture the change in purchasing power, the net worth q' that enters the utility function for bequests is deflated by a price index $\alpha + (1 - \alpha)p_h$.

To compute a transitional equilibrium, we first choose a sequence of mortgage interest deductibility parameters $\{\tau_t^m\}_{t=1}^{t=T}$, where T is the last transition period. We then solve for the sequences of house and rental prices, $\{p_{ht}, p_{rt}\}_{t=1}^{t=T}$, and the sequences of the parameters governing the average labor income tax rate $\{\lambda_t\}_{t=1}^{t=T}$ and the bequest rate $\{\gamma_t\}_{t=1}^{t=T}$, such that for all $t \in \{1, ..., T\}$, total housing demand equals the initial housing stock, tax neutrality is achieved, and any changes in bequests are distributed to the households. In the transition, the removal policies are implemented unexpectedly and households have perfect foresight of the transition paths of the deductibility parameter, house and rental prices, as well as the tax and bequest parameters. Any unexpected change in the house price in the first period of the transition, affects the profits of the rental companies. We assume that any profit changes in the first period of the transition are distributed to the homeowners in proportion to their cash-on-hand x. For a detailed description of the equilibrium definitions, the computational methods, and the solution algorithms, see the Appendices.

1.3 The MID and the benefit of owning

To better grasp the mechanisms behind the results in this paper, it is useful to understand why households want to own a house in the model and how this is affected by the MID. Our discussion builds upon previous work on the user cost of owning by, e.g., Díaz and Luengo-Prado (2008), but here we distinguish between those who itemize deductions and those who do not, as this is central to our analysis. We compare a household who owns a house of size h' to a similar household who instead obtains the equivalent housing service $s = h'$ on the rental market. The ex-post net benefit of owning NB^{Own}, in any period, is given by

$$NB^{Own} = UC^{Rent} - UC^{Own}, \tag{1.14}$$

where UC^{Rent} is the user cost of renting and UC^{Own} is the user cost of owning. Intuitively, the net benefit of owning is positive whenever owning is less costly as compared to renting.

The user cost of renting is given by $p_r s$, i.e., the rental price times the size of the rental unit. The user cost of owning is more complicated, as an owned house is an asset that comes with the possibility of debt financing. To keep the analysis in this section tractable, we make a few simplifying assumptions as compared to the full model. First, we abstract from any risk by assuming that prices are constant over time and that the earnings in the next period y' are known. Second, we assume that the interest rate on mortgages r^m is equal to the risk-free rate r. Third, we abstract from the possibility of selling and buying a house and hence, from the transaction costs that occur when doing so. Fourth, we assume that local labor income taxes are not tax deductible.

Given the modifications to the full model, the user cost of owning includes the sum of four costs. First, there is a maintenance cost of $\delta^h h'$. Second, there is an opportunity cost of equity. If the equity had not been invested in the house, it would have yielded an after tax return of $\tilde{r}(p_h h' - m')$, where $\tilde{r} \equiv (1 - \tau^c)r$ is the net of tax risk-free rate. Third, a homeowner needs to pay a property tax on the house. This property tax cost is modeled as a fixed share of the house value, and is given by $\tau^h p_h' h'$. Last, a homeowner incurs a cost whenever it uses a mortgage to finance its dwelling. The borrowing cost is simply the interest payment on the mortgage rm'.

The costs of owner-occupied housing can be reduced whenever a homeowner chooses to itemize deductions rather than simply opt for a standard deduction. The sum of the itemized deductions amounts to $ID' = \tau^h p_h' h' + \tau^m r m'$, and is subtracted from earnings which, in turn, are subject to the progressive tax schedule $T(\tilde{y}')$. Importantly, any itemized deductions in excess of the standard deduction reduce the tax liabilities of the homeowner and therefore lower the effective cost of property taxes and mortgage financing. The total benefit from being able to itemize deductions is given by

$$I^d \int_{SD}^{ID'} T_{\tilde{y}'}(y' - \hat{D}) d\hat{D},$$

where I^d is an indicator variable for itemized tax deductions. The user cost of owning is the present value of the sum of all costs, adjusted for deductions

$$UC^{Own} = \frac{1}{1+\tilde{r}} \left(\delta^h h' + \tilde{r}(p_h h' - m') + \tau^h p_h' h' + rm' - I^d \int_{SD}^{ID'} T_{\tilde{y}'}(y' - \hat{D}) d\hat{D} \right). \quad (1.15)$$

Substituting equations (1.9) and (1.15) into (1.14), we get

$$NB^{Own} = \frac{1}{1+\tilde{r}} \left[(\delta^r - \delta^h) h' + \tau^c r (p_h h' - m') + I^d \int_{SD}^{ID'} T_{\tilde{y}'}(y' - \hat{D}) d\hat{D} \right]. \quad (1.16)$$

The first term is the benefit of owning due to a lower depreciation of owned housing as compared to rental housing. The second term is the benefit of investing equity in an asset (housing) where the return is not taxed, compared to investing in bonds where the return is taxed at a rate τ^c. This benefit to owner-occupied housing arises because the imputed rent is not taxed. The last term consists of the tax benefits of owner-occupied housing due to property tax and mortgage interest deductions. Thus, the above measure of the net benefit of owning encapsulates the main features of the U.S. tax treatment of housing.

To see how the net benefit of owning is affected by the deductibility parameter τ^m, it is useful to take the derivative of equation (1.16) with respect to mortgages

$$NB_{m'}^{Own} = \frac{1}{1+\tilde{r}} \left[-\tau^c r + I^d T_{\tilde{y}'}(y' - ID') \tau^m r \right]. \quad (1.17)$$

An increase in the mortgage level, and consequently a reduction in equity, has two effects on the net benefit. On the one hand, the reduction in equity means a smaller benefit resulting from the lack of taxation of imputed rent, which is captured by the first term. On the other hand, since mortgage interest payments are tax deductible ($\tau^m = 1$ in the initial steady state), the increased mortgage results in larger deductions and hence a higher net benefit.

Overall, equations (1.16) and (1.17) are key to understanding how the MID affects the net benefit of owning and, subsequently, the demand for owner-occupied housing. First, the MID increases the net benefit of owning by decreasing the cost of mortgage financing only for those who itemize deductions. In the full model, itemizing households are those with relatively large mortgages, houses, or earnings, or a combination of the three. Second, the net benefit of owning due to mortgage interest deductions is increasing in the marginal tax rate. Figure 1.2 illustrates that the marginal tax rate differs substantially between households, leading to significant differences in the user cost of owning between households. Third, the net benefit of owning is positive regardless of the MID, due to the difference in the depreciation rates, the lack of taxation of the imputed rent, and the property tax deduction. In the full model, transaction costs, borrowing constraints, the mortgage interest spread, and the minimum size of owner-occupied housing hinder some households from owning and make some households prefer renting.

1.4 Calibration

We calibrate the model to the U.S. economy. To avoid capturing business-cycle movements in the data, calibration figures are taken from pooled data over the period 1989 - 2013, subject to data availability. Most of our parameters are calibrated independently, based on data or previous studies, whereas the remaining parameters are calibrated using simulated method of moments.

1.4.1 Independently calibrated parameters

Yearly parameter values taken from other studies or calculated directly from the data are listed in Table 1.1.

Parameter	Description	Value
σ	Coefficient of relative risk aversion	2
τ^l	Local labor income tax	0.05
τ^c	Capital income tax	0.15
τ^{ss}	Payroll tax	0.153
τ^h	Property tax	0.01
τ^m	Mortgage interest deductibility	1
r	Interest rate	0.03
κ	Yearly spread, mortgages	0.014
γ	Bequest rate	0
θ	Down-payment requirement	0.20
ψ	Payment-to-income requirement	0.28
δ^h	Depreciation, owner-occupied housing	0.03
ς^I	Home insurance	0.005
ς^b	Transaction cost if buying house	0.025
ς^s	Transaction cost if selling house	0.07
ς^r	Refinancing cost	3.0
R	Replacement rate for retirees	0.5
B^{max}	Maximum benefit during retirement	51.1

Table 1.1: Independently calibrated parameters, based on data and other studies

Note: The table presents calibrated parameter values. The values are annual for relevant parameters. When simulating the model, we adjust these values to their three-year (one model period) counterparts. The refinancing cost ς^r and the maximum benefit during retirement B^{max} are in 1000's of 2013 dollars.

Demographics and preferences

The households enter the economy at age 23. The probability of a household dying between two consecutive ages is taken from the Life Tables for the U.S. social security area 1900-2100 (see Bell and Miller (2005)). We use the observed and projected mortality rates for males born in 1950. In the model, the retirement age is set to 65, and we assume that all households are dead by the age of 83. Using data from the Panel Study of Income Dynamics (PSID), we specify the equivalence scale e_j as the square root of the predicted values from a regression of family size on a third-order polynomial of age. In the CRRA utility function, we set the coefficient of relative risk aversion σ to 2, which is widely used in the literature.

Assets and bequests

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

The parameter γ, which determines how much bequests each household receives, is set to zero in the initial steady state. When conducting the policy experiments, this parameter is adjusted to account for changes in bequests.

Tax system

The local labor income tax rate τ^l is set to 0.05, which is the average state and local labor income tax rate for itemizers in 2011 (Lowry, 2014). The capital income tax τ^c is set to 0.15, to match the maximum rate that applies to long-term capital income for most taxpayers. In the U.S., the payroll tax is levied equally on both the employer and the employee, and amounts to 15.3 percent of earnings (Harris, 2005). Since there is no explicit production sector in our model, we let the full tax burden fall on the worker by setting τ^{ss} to 0.153. The American Housing Survey (AHS) shows that the median amount of real estate taxes per $\$1,000$ of housing value is approximately 10 dollars.[11] Following this estimate, we set the property tax parameter τ^h to 0.01.

The mortgage interest deductibility rate τ^m is our parameter of interest. In the analysis we alter this parameter from one to zero, where the benchmark economy is characterized by full deductibility (τ^m=1).

Market setting

The interest rate is estimated from market yields on the 30-year constant maturity nominal Treasury securities, deflated by the year-to-year headline Consumer Price Index (CPI). The average real rate over the period 1997 to 2013 is 3.4 percent (Federal Reserve Statistics Release, H15, and the Bureau of Labor Statistics, Databases & Tables, Inflation & Prices). We set the real interest rate r to 0.03. Using the Federal Reserve's series of the contract rate on 30-year fixed-rate conventional home mortgage commitments over the period 1997 to 2013, we find that the average yearly spread to the above Treasuries is 1.4 percentage points. Consequently, we choose a yearly spread for mortgages κ of 0.014, implying a mortgage interest rate r^m of 0.044.

Similar to Floetotto et al. (2016) and Sommer and Sullivan (2018), we set the minimum down-payment requirement θ to 0.20 in the model. The payment-to-income requirement ψ is taken from Greenwald (2018) and is set to 0.28.

The depreciation rate of owned housing is set to 3 percent. This follows from the estimate of the median depreciation rate of owned housing, gross of maintenance, in Harding et al. (2007). The transaction costs of buying and selling a house are taken from Gruber and Martin (2003). They use the median transaction costs from CES data

[11] See table C-10-OO in the 2011 and 2013 American Housing Survey, and table 3-13 in the 2009 wave.

and estimate the costs of buying and selling to be 2.5 and 7 percent of the house value, respectively. The home insurance is calibrated to match the median property insurance payment in the AHS. In the 2013 AHS, this is roughly half of the median property tax payments, thus we set ς^I to 0.005.

The fixed refinancing cost ς^r is set to 3,000 in 2013 dollars and is the sum of application, appraisal, inspection, and survey fees, along with attorney review, and title search and insurance costs. Data on the different costs are taken from the Federal Reserve. We use the average of the low and high estimates for these costs.[12]

Labor income

In this section, we outline the central elements of our estimation procedure, and relegate a more detailed description of the data and estimation method to Appendix 1.D. The labor income process is similar to that of Cocco et al. (2005). We estimate a deterministic life-cycle profile of earnings and include the idiosyncratic earnings risk via permanent and transitory shocks. At each age j, household i receives exogenous earnings y_{ij}. For any household, the log earnings before retirement are

$$\log(y_{ij}) = \alpha_i + g(j) + n_{ij} + \nu_{ij} \quad \text{for } j \leq J_{ret}, \tag{1.18}$$

where α_i is a household fixed effect with distribution $N(0, \sigma_\alpha^2)$. The function $g(j)$ represents the hump-shaped life-cycle profile of earnings. The remaining two terms, ν_{ij} and n_{ij}, capture the idiosyncratic earnings risk. The former is an i.i.d. transitory shock with distribution $N(0, \sigma_\nu^2)$. The latter, n_{ij}, allows for households' earnings to permanently deviate from the deterministic trend, and is assumed to follow

[12]For the estimates of the different costs, see "A consumer's guide to mortgage refinancing", available at
https://www.federalreserve.gov/pubs/refinancings/default.htm.

a random walk

$$n_{ij} = n_{i,j-1} + \eta_{ij} \quad \text{for } j \leq J_{ret}, \tag{1.19}$$

where η_{ij} is an i.i.d. shock, distributed $N(0, \sigma_\eta^2)$. All shocks are assumed to be uncorrelated with each other. Note that log earnings are represented by the sum of a permanent component, $\log(z_{ij}) = \alpha_i + g(j) + n_{ij}$, and a transitory component ν_{ij}. The permanent earnings state variable in the model is given by z_{ij}.

During retirement there is no earnings risk. Households receive benefits given by

$$\log(y_{ij}) = \min\left(\log(R) + \log(z_{i,J_{ret}}),\ \log(B^{max})\right) \quad \text{for } j \in]J_{ret}, J], \tag{1.20}$$

where R is a common replacement rate for all households and B^{max} is the maximum amount of benefits a household can receive. For simplicity, retirement benefits are a function of permanent earnings in the last period before retirement only.

Equations (1.18) and (1.19) are estimated using PSID data for the survey years 1970 to 1992, following Cocco et al. (2005). The deterministic life-cycle profile $g(j)$ is estimated by regressing log household earnings on dummies for age, marital status, family composition, and education. We control for household fixed effects by running a linear fixed effect regression. A third-order polynomial is fitted to the mean predicted earnings by age.

The variances of the transitory σ_ν^2 and permanent σ_η^2 shocks are estimated in a similar fashion as in Carroll and Samwick (1997). The variance of the fixed effect shock σ_α^2 is identified as the variance of earnings, net of the deterministic trend value in the first period of working life, that is not explained by the estimated variances of the transitory and the permanent shocks. Table 1.2 presents the resulting variances.

Parameter	Description	Value
σ_α^2	Fixed effect	0.095
σ_η^2	Permanent	0.030
σ_ν^2	Transitory	0.028

Table 1.2: Estimated variances of three-year shocks
Note: During working age, households receive permanent and transitory earnings shocks. In addition, households obtain a fixed effect shock when they enter the economy. During retirement there is no earnings risk. Estimated using PSID data.

The maximum allowable benefit during retirement, B^{max} in equation (1.20), is calculated using data from the Social Security Administration (SSA). The common replacement rate R is set to 50 percent, as in Díaz and Luengo-Prado (2008).

1.4.2 Estimated parameters

Table 1.3 shows the structural parameters calibrated by simulated method of moments, along with a comparison between data and model moments. Unless otherwise stated, we use data from the SCF, where we pool the 1989 to 2013 survey years.

Although all the parameters are jointly determined in the simulated method of moments, some parameters are especially important for some moments. The discount factor β impacts households' savings and borrowing decisions. Hence, this parameter is used to match the median LTV. The depreciation rate of rental housing δ^r affects how favorable owner-occupied housing is relative to rental housing, which in turn impacts how early in life households become homeowners. Therefore, this parameter is used to target the homeownership rate for those under the age of 35. The minimum owner-occupied house size $\underline{h}$ is calibrated to match the overall homeownership rate. The parameter α determines the weights on consumption and housing services in the utility function. We use this parameter to calibrate the median house value relative to earnings, conditional on owning.

Parameter	Description	Value	Target moment	Data	Model
β	Discount factor	0.93	Median LTV	0.35	0.35
δ^r	Depreciation rate, rentals	0.047	Homeownership rate, age < 35	0.44	0.44
$\underline{\mathrm{h}}$	Minimum owned house size	137.0	Homeownership rate	0.70	0.70
α	Consumption weight in utility	0.76	Median house value-to-earnings	2.30	2.30
$\bar{q}$	Luxury parameter of bequest	135.6	Net worth p75/p25, age 68-76	5.30	5.61
υ	Utility shifter of bequest	6.5	Median net worth, age 75/50	1.43	1.43
λ	Level parameter, tax system	1.66	Average marginal tax rates	0.13	0.13
SD	Standard deductions	8.02	Itemization rate	0.53	0.53
τ^p	Progressivity parameter	0.14	Distr. of marginal tax rates	See text	

Table 1.3: Estimated parameters
Note: Parameters calibrated by simulated method of moments. The third column shows the resulting parameter values from this estimation procedure. The values are annual when applicable. When simulating the model, we adjust these parameter values to their three-year (one model period) counterparts. The minimum owned house size $\underline{\mathrm{h}}$ and the standard deduction SD are in 1000's of 2013 dollars. The fifth column presents the values of data moments that are targeted. The last column shows the model moments that are achieved by using the parameter values in column three.

The bequest function has two parameters; $\bar{q}$ determines the extent to which bequests are luxury goods, and υ determines the strength of the bequest motive. The former is calibrated to capture the dispersion in net worth among old households, measured as the ratio of net worth in the 75th percentile to the 25th, for ages 68 to 76. The latter is calibrated to fit the difference in net worth between working-age and retired households. As a target, we use the ratio of median net worth for ages 75 and 50. We use the parameter λ, which governs the level of the convex tax and transfer function $T(\tilde{y})$, to target the average marginal tax rate. The target is taken from Harris (2005). We calibrate the standard deduction to match the fraction of the working-age population that itemize tax deductions. Using self-reported rates for working-age households, the itemization rate is 0.53.[13] Our calibrated standard deduction is about $8,000$ in 2013 dollars, which is within

[13]In this case, we do not include households aged 23-25 when we compute the model moment. These ages correspond to the first model period, where households by construction cannot deduct property taxes or mortgage interest payments. Hence, the itemization rate is artificially low in the model for this age group.

the range of standard deductions available to single filers ($6,100) and married households filing jointly ($12,200) in 2013.

The parameter determining the progressivity of the federal labor income tax τ^p, is set to match the distribution of households exposed to the different statutory marginal tax rates. We minimize the sum of the absolute values of the differences between the shares of households exposed to the statutory tax brackets in data compared to in the model. For this estimation procedure, we allocate households to their nearest tax bracket in the model, and we use data on shares from the Congressional Budget Office in 2005 (Harris, 2005). The statutory tax brackets we use are consistent with the tax code from 2003 to 2012 (The Tax Foundation, 2013). The resulting progressivity parameter value is 0.14, which is close to that in Heathcote et al. (2017). Figure 1.1 displays the fractions of the working-age population exposed to the different statutory marginal tax rates in the data (Harris, 2005) versus in the model.

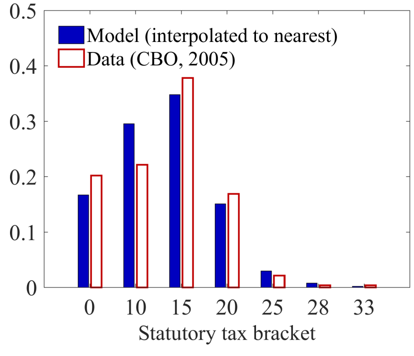


Figure 1.1: Fractions of taxpayers facing different marginal tax rates
Note: The model refers to the results from the initial steady state with MID. For comparison purposes, we interpolate households' marginal tax rates to the nearest tax brackets, as the labor income tax schedule is continuous in the model. The data is from Harris (2005).

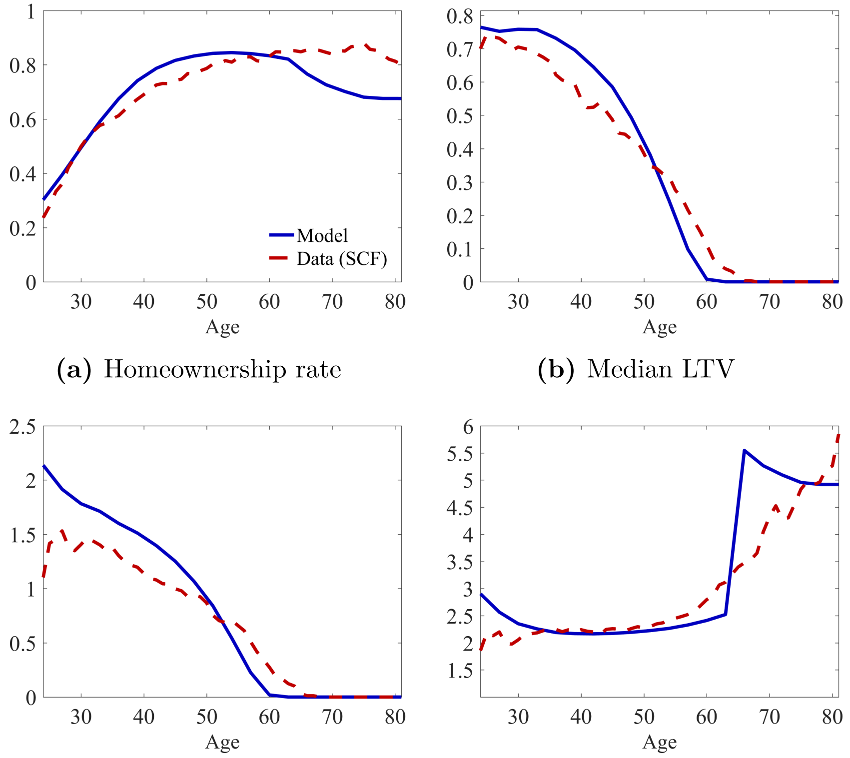
1.4.3 Model fit

As is evident in Table 1.3, the calibration enables the model to successfully hit the target moments. However, the reliability of our results does not only depend on how well the model performs with respect to aggregate measures. It also depends on the distributions and life-cycle profiles of relevant variables.

The life-cycle profiles of homeownership, LTV, and mortgage-to-earnings are key indicators of the heterogeneity in exposure to the mortgage interest deductibility. Comparisons to SCF are displayed in Figure 1.2. The model performs well with respect to these variables, both in terms of magnitudes and life-cycle patterns, although there are some discrepancies. The model also produces a decent fit of the median house-to-earnings, which is a measure of exposure to price changes in the housing market. The jump in the median house-to-earnings at age 65 in the model is a result of households retiring with certainty at that age.

Data on U.S. tax returns and the SCF show that the fraction of households that itemize deductions is increasing in earnings and that there is a strong skewness in MID claims.[14] In the 2013 tax filings, only about four percent of those earning less than $\$15,000$ (24 percent of all returns) itemized deductions, and they merely claimed two percent of all mortgage interest deductions. This stands in sharp contrast to comparable numbers for those earning more than $\$100,000$ (top 15 percent). They claimed 55 percent of the total mortgage interest deductions, and more than 82 percent used itemized deductions. A similar skewness is apparent in the SCF, although somewhat less pronounced. As seen in Figure 1.3a and Figure 1.3b, our model is able to replicate these important patterns: high earners itemize the most

[14]The tax return data is publicly available at the IRS webpage. We use data from "SOI tax stats - individual statistical tables by size of adjusted gross income", tables 1.4 and 2.1.

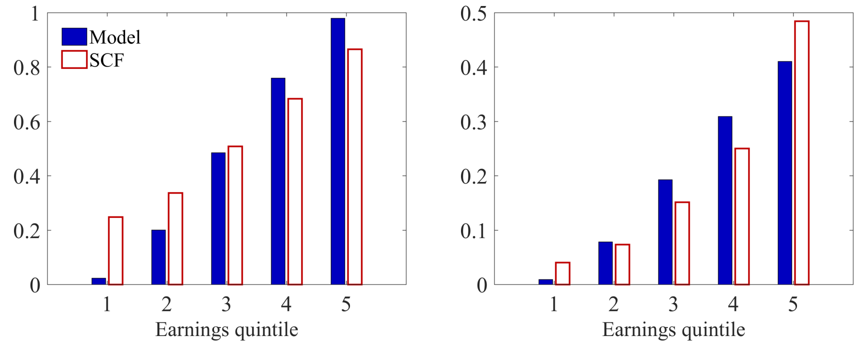


(a) Homeownership rate **(b)** Median LTV

(c) Median mortgage-to-earnings **(d)** Median house-to-earnings

Figure 1.2: Comparison of model versus data: non-targeted profiles
Note: The model refers to the results from the initial steady state with MID. The data is taken from Survey of Consumer Finances (SCF), survey years 1989-2013.

and claim a disproportionately large share of the mortgage interest deductions.



(a) Fractions that itemize

(b) Fractions of mortgage interest deductions

Figure 1.3: Itemizers and MID claims in the initial steady state, across earnings quintiles

Note: Working-age households only. The data is taken from the SCF, survey years 1995-2013 (the data on itemization is missing in the 1989 and 1992 waves). Mortgage interest deductions are computed from reported mortgages and interest rates for those who itemize.

1.5 Results

1.5.1 What are the long-run effects of removing the MID?

What would the level of house prices in the U.S. be if households were not able to deduct mortgage interest payments? Does the MID promote homeownership? What fraction of American households would prefer to be born into a world without the MID, and how much would they gain or lose?

These questions regarding the long-run implications of removing the MID are all addressed in this section. Although the focus of this paper is on the transitional dynamics of repealing the MID, the answers to these questions are also relevant for our purpose. Indeed, it is difficult to motivate a study of the short-run dynamics if the long-run welfare effects are negative. Moreover, the key mechanisms in the long run are also at work in a transition.

In order to study the long-run effects of removing the MID, we compare the initial steady state with MID to a new steady state in which the possibility to deduct mortgage interest payments is repealed. Specifically, we study the effects of changing the deductibility parameter τ^m from the initial value of one to zero, while imposing tax neutrality and accounting for changes in bequests. The labor income tax level parameter λ is adjusted so that the net tax revenue for the government is unchanged between the steady states. We alter the bequest parameter γ to distribute any changes in bequests.

Prices and aggregates

Table 1.4 presents a comparison of the two steady states for a number of key variables. Overall, the new steady state without MID is characterized by lower house and rental prices, higher homeownership, reduced indebtedness, lower taxes, and more bequests. The price decrease is driven by a downward shift in the demand for housing among homeowners who often itemize. These households experience an increase in the user cost of owning, as discussed in section 1.3. If the house price is held constant, households in this group would wait longer until they buy their first house, and buy smaller houses. When the house price is allowed to decline, households who often itemize do no longer postpone their house purchases, but they still demand smaller houses. Overall, in the new steady-state equilibrium, the homeownership is virtually unchanged for this group of households, whereas they demand smaller houses.

For those who seldom itemize, the lower house price has a positive effect on homeownership. Some households who would never own a house in the initial steady state are homeowners in the new steady state. Indeed, the fraction of households that own a house at some point in life increases by about one percentage point (see *fraction ever-*

owner in Table 1.4). Moreover, those who own a house but seldom itemize in the initial steady state choose to buy their first house earlier in the new steady state. Overall, the homeownership rate increases by approximately one percentage point to around 71 percent. This result confirms the findings and the underlying mechanism in Sommer and Sullivan (2018). They document that removing the MID is associated with an increase in the homeownership rate due to the fall in the house price.

In Table 1.4, we see that the mean mortgage level decreases significantly. This is primarily driven by households that often itemize. The fall in the mortgage level is not only caused by the higher cost of mortgage financing, but also by the change in house sizes and the fall in the house price. Since it is the itemizing households that demand smaller houses and are directly affected by the MID, they are also those that decrease their mortgage levels the most.

	MID	No MID	Relative difference (%)
House price	1	0.965	-3.47
Rental price	0.238	0.234	-1.66
Homeownership rate	0.70	0.71	1.88
Fraction ever-owner	0.88	0.89	1.59
Mean owned house size	215	211	-2.15
Mean LTV	0.36	0.31	-12.09
Mean mortgage	74	60	-19.29
Mean bond holdings	20.6	21	1.81
Mean marginal tax rate	0.150	0.146	-2.59
Mean bequest collected	152	158	3.57

Table 1.4: Long-run effects on prices and aggregates of removing the MID
Note: The first column shows prices and aggregate measures in the initial steady state with MID, whereas the second column shows the corresponding values in the steady state without MID. The rental price corresponds to a three-year (one model period) cost of renting. "Fraction ever-owner" is the fraction of households that own a house at some point during their life. The mean house size, LTV, and the mortgage level are conditional on owning. The mean owned house size, mortgage, bond holdings, and bequest collected are in 1000's of 2013 dollars. The mean marginal tax rate is gross of deductions.

Why are U.S. households better off without the MID in the long run?

We use the ex-post consumption equivalent variation (CEV) as our welfare measure. This is defined as the per-period percentage change in realized consumption that is required in the steady state with MID to make a household indifferent to an economy without MID. Formally, let $\tilde{V}$ be the discounted welfare and $(\tilde{c}_{i,j}, \tilde{s}_{i,j}, \tilde{q}'_{i,j})$ be the realized consumption, housing services, and net worth in the steady state without MID,

$$\tilde{V} \equiv \sum_{j=1}^{J} \left(\beta^{j-1} \prod_{k=1}^{j-1} \phi_k \right) \left[U_j(\tilde{c}_{i,j}, \tilde{s}_{i,j}) + \beta(1-\phi_j) U^B(\tilde{q}'_{i,j}) \right].$$

Then, for each household we solve for Δ that makes the discounted welfare under the two tax regimes equal

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

where $(c_{i,j}, s_{i,j}, q'_{i,j})$ are the realizations of each variable in the steady state with MID. If we set Δ to zero, the left-hand side of this equation is simply the discounted welfare in the initial steady state. In the remainder of the paper we will refer to Δ as CEV. We are also interested in what fraction of households that benefit from a removal, which we define as the share of households with a CEV greater than or equal to zero.

An overwhelmingly large fraction, 88 percent of households, are better off being born into the steady state without MID, see the last column in Table 1.5. On average, the welfare gain of being born into the steady state without MID is equivalent to that of increasing consumption by 0.91 percent in all periods in the initial steady state.

The direct effect of no longer having the mortgage subsidy is negative as seen in the first column of Table 1.5. Yet a large fraction of households experience a small or no loss. Even with MID in place, many households do not itemize deductions. In addition, as seen in Figure 1.3b, the amounts of mortgage interest deductions are highly skewed. Households with higher earnings claim a disproportionately large share of the total mortgage interest deductions. Most itemizing households deduct relatively modest amounts of mortgage interest payments.

There are three equilibrium effects that improve households' welfare: the lower house and rental prices, the lower labor income taxes, and the increased bequests. The lower house price in the steady state without MID makes both rental and owner-occupied housing more affordable, which increases welfare. Importantly, the lower house price reduces the equity requirement and makes the PTI requirement less stringent. This enables more households to become homeowners and allows some households to purchase a house earlier. In the second column in Table 1.5, we see that the price adjustment is sufficient to create significant positive welfare effects, and 74 percent would prefer to live in a world without MID. The lower labor income tax and the increased bequests in the new steady state further increase the welfare for all households. Households at the top of the earnings distribution constitute the only group for which the direct negative effect of removing the MID outweighs the benefits of lower equilibrium prices and taxes and higher bequests.

1.5.2 What are the effects of an immediate removal of the MID?

Our results in the previous section suggest that U.S. households would be considerably better off in a world in which they cannot deduct mortgage interest payments. However, the long-run analysis does not touch upon another important question: is a repeal of the MID also

Mean CEV (%)	-0.54	0.32	0.78	0.91
Fraction in favor	0.15	0.74	0.85	0.88
Rental and house prices adjust	-	✓	✓	✓
Tax neutrality	-	-	✓	✓
Bequests adjust	-	-	-	✓

Table 1.5: Long-run welfare effects of removing the MID, for newborns
Note: Mean CEV (%) refers to the average consumption equivalent variation in percent, for newborns. For example, the average welfare effect of removing the MID when house prices, taxes, and bequests adjust is equivalent to a 0.91 percent increase in consumption in all periods, in the initial steady state. The fraction in favor is the fraction of newborns with a CEV greater than or equal to zero.

beneficial for current households? To shed some light on this question, we need to consider the short-run effects. In this section, we present the results of an immediate removal of the MID, i.e., $\tau_t^m = 0$ for all $t \geq 1$.

Who are the winners and losers from a reform?

In order to evaluate the welfare effects of the immediate removal, we consider the lifetime gains and losses incurred by households alive when the policy is implemented. These welfare effects can differ markedly from the long-run analysis, as households have made long-term decisions based on the presumption that they can deduct mortgage interest payments. As is shown in the analysis below, the welfare effects therefore tend to be significantly lower and much more dispersed.

Similar to the steady-state analysis, there are four main factors influencing how a household is affected by the removal policy. First, households that itemize deductions and have a mortgage are directly negatively affected by a reduction of the MID. Second, the sudden fall in the house price, as seen in Figure 1.4, reduces the home equity for existing homeowners, while renters benefit from less stringent constraints in the housing market and lower rental prices. Third, all households are positively affected by an instant fall in the labor income tax level since the government no longer subsidizes mortgage financing. Finally, the unexpected fall in the house price lowers the values of bequests, which affects all households negatively. A detailed overview of the transitional dynamics is presented in Section 1.5.3, where we compare the immediate policy to alternative removal policies.

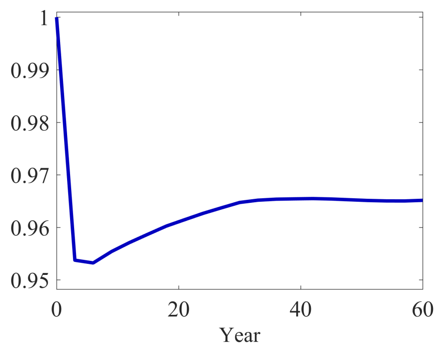


Figure 1.4: House price dynamics from an immediate removal of the MID

On average, the immediate removal policy results in significant welfare losses for current U.S. households. The average welfare effect of an immediate removal is equivalent to a 0.4 percent decrease in consumption in all remaining periods in the initial steady state and only 39 percent would gain from such a reform. This stands in sharp contrast to the long-run analysis, where 88 percent would benefit from a world without MID.

Furthermore, we could not find a one-time cash transfer scheme that, in combination with the removal, would lead to a Pareto improvement. Taxing all winners and compensating all losers such that every household is indifferent between a reform and no reform would produce a transfer-scheme deficit of 1.2 percent of average cash-on-hand.

The aggregate results mask important heterogeneous welfare effects.

Figure 1.5 displays the distribution of welfare changes in the first period of the transition. Based on this distribution, we allocate households into four groups as indicated by the vertical lines in the figure. The first group contains the households who experience the largest welfare losses in the transition. The second group contains the households with less extreme, but still sizable negative CEVs. The third group is made up by a mass of households that have CEVs around zero. The households in the right bell of the distribution are allocated to the fourth group. Table 1.6 presents key characteristics for the different groups.

The bimodal shape of the CEV distribution stems from differences in welfare effects between homeowners and renters. The mass around the right-hand peak consists of renters, while the mass around the left-hand peak, groups one to three, consists of homeowners. Renters are not directly affected by the removal of the MID, but benefit from the lower rental price, relaxed LTV and PTI constraints in the housing market, and lower taxes.

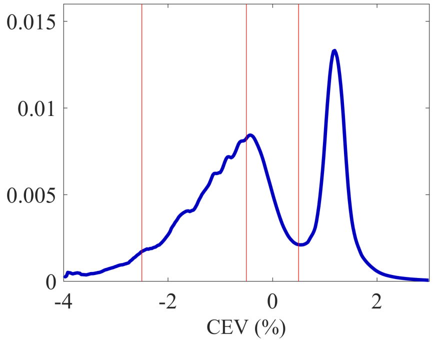


Figure 1.5: The distribution of welfare effects under the immediate removal policy

Note: CEV (%) refers to the ex-post consumption equivalent variation in percent, for all households that are alive in the first period of the transition. The vertical lines allocate households into different groups based on their welfare effects. See Table 1.6 for key characteristics of these groups.

Group:	1	2	3	4
CEV range:	< -2.5	$[-2.5, -0.5[$	$[-0.5, 0.5[$	≥ 0.5
Working age:				
Mean CEV	-3.09	-1.18	-0.13	1.23
Homeownership rate	1	0.98	0.87	0.03
Itemization rate	0.99	0.84	0.56	0.01
Age	38	45	47	37
Earnings	133	106	85	44
House size	310	231	180	165
Mortgage	219	119	67	71
LTV	0.71	0.54	0.41	0.42
Retirement age:				
Mean CEV	-4.57	-1.39	-0.19	1.19
Homeownership rate	1	1	1	0.03
Age	79	70	68	74
Earnings	42	40	28	15
House size	235	218	161	146
LTV	0.02	0.03	0.05	0.07

Table 1.6: Characteristics of winners and losers in the short run
Note: Groups 1 to 4 correspond to the four groups indicated by the vertical lines in Figure 1.5. Thus, the welfare effects are those experienced under the immediate removal policy. Other measures correspond to mean values of households in the event that the MID is not repealed. House size, mortgage, and LTV are conditional on owning a house. Earnings, house size, and mortgage are in 1000's of 2013 dollars.

Homeowners realize several negative effects in the short run, but the extent to which they are affected varies with the household characteristics. By comparing the three groups of homeowners in Table 1.6, we see that the CEV is decreasing in mortgages, permanent earnings, and the itemization rate for working-age households. Homeowners with larger mortgages and higher earnings benefit more from itemizing deductions. Consequently, they are relatively worse off when they can no longer deduct mortgage interest payments, as represented by the long, thick tail of negative values in Figure 1.5. Table 1.6 also shows that households with lower CEVs on average own larger houses, which primarily reflects that these households are high earners. In addition, younger homeowners tend to be worse off. This mainly follows from younger homeowners having higher LTVs. For retired households, the very old with large houses are the biggest losers. These households rely heavily on housing equity as they have low earnings relative to wealth, and thus suffer significantly from the house price fall.

The transition also entails positive effects for homeowners, although these are generally outweighed by the negative effects. All homeowners benefit from the lower labor income taxes when the MID is removed, as well as the decreased property tax payments following the fall in the house price.

The results in Table 1.6 also help explain why a one-time cash transfer between households cannot achieve a Pareto improvement. Not only is a majority of households against the reform, but those who are hurt by the removal tend to have higher life-time earnings. This negative correlation between income and welfare implies that relatively large transfers in absolute terms are required to compensate the losers.

Why do we find negative welfare effects?

Other papers that have studied the short-run welfare effects of removing the MID find that a majority of households would benefit from an immediate policy; see Floetotto et al. (2016) and Sommer and Sullivan (2018). Our model differs from those in earlier papers along a variety of dimensions. Although our model does not nest theirs, three major modeling features account for most of the differences in the welfare effects relative to Sommer and Sullivan (2018), which is arguably the paper closest to ours in terms of modeling. These features include having a refinancing cost of mortgages, an explicit modeling of households in retirement, and accounting for changes in bequests caused by a lower house price in the transition.

A refinancing cost of mortgages makes housing equity less liquid and it is more difficult for homeowners to cushion negative shocks. The refinancing cost makes it costly to increase a mortgage, and it is only worthwhile to increase a mortgage by a relatively large amount. In the transition, the house price decline limits the amount by which households can increase their mortgage, through the LTV constraint. Thus, households who receive negative shocks during the transition are less inclined to use housing equity to smooth their consumption, resulting in lower welfare. Furthermore, refinancing costs lead to a larger house price decline early in the transition, through a similar mechanism. In an economy where mortgage refinancing is costly, households are more inclined to get access to their housing equity by selling their home, which has a negative impact on the aggregate price level.

As we explicitly model the full life-cycle of households, we are able to study the welfare effects of retirees. We find that homeowners in retirement are relatively worse off when the MID is removed. Older households hold more housing wealth, and their housing wealth relative to earnings is substantially higher as depicted in Figure 1.2d. Furthermore, older households have fewer periods left to smooth the negative wealth shock resulting from the house price drop. Finally, because retirees have a higher probability of dying, they care more about the bequests they leave behind. Thus, for many retirees, the unexpected fall in net worth in the transition lowers their welfare.

In our analysis, households are also negatively affected by a reduction in the values of bequests received. This is crucial at the beginning of the transition when the house price fall sharply reduces wealth. When households receive less bequests, there is a reduction in welfare. In contrast, Sommer and Sullivan (2018) use a standard assumption that any accidental bequests are fully taxed and that the government spends this revenue on activities that do not affect any agents in the economy.

In a calibration where we remove the cost of refinancing, consider the welfare effects of the working-age population only, and do not distribute changes in bequests, we find a positive average welfare effect

Mean CEV (%)	0.03	-0.14	-0.22	-0.40
Fraction in favor	0.52	0.46	0.41	0.39
Include welfare retirees	-	✓	✓	✓
Bequests adjust	-	-	✓	✓
Refinancing cost	-	-	-	✓

Table 1.7: Model features that can explain our negative welfare result
Note: Welfare results of an immediate removal policy. The first column shows the results from a model specification where we do not: i) include the welfare effects of retirees; ii) adjust bequests received by households; and iii) include refinancing costs of mortgages. The last column shows our benchmark result. The fraction in favor is the fraction of households with a CEV greater than or equal to zero. For a description of CEV (%) see *Note* below Figure 1.5.

that is more in line with previous studies. In the first column of Table 1.7, we can see that under these assumptions, the average CEV is 0.03 percent and a majority (52 percent) of households are in favor of an immediate removal of the MID. Moreover, the results in this table suggest that all three model features are central for understanding why our welfare results are lower than those in Sommer and Sullivan (2018).

1.5.3 Do households prefer more gradual removal policies?

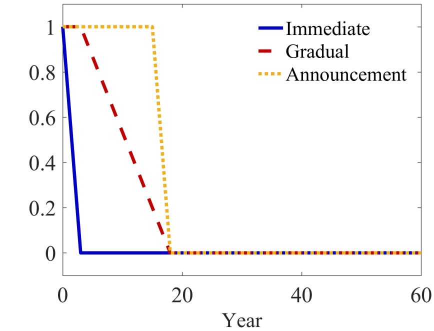
In the previous section, we show that an immediate removal of the MID results in considerable negative welfare effects on average. The negative effects are primarily driven by homeowners who can no longer deduct mortgage interest payments and who suffer from losses in their housing equity. Given the large positive long-run welfare effects of an MID removal, an investigation of alternative removal policies that could potentially improve the welfare effects for homeowners is warranted.

To enable homeowners to adjust their asset allocations before the MID is repealed, we consider two policies in which the MID is removed less rapidly.[15] Under a *gradual* policy, households can deduct mortgage interest payments for another 15 years (5 model periods), but the deductible share is reduced stepwise over that period such that $\{\tau_t^m\}_{t=1}^{t=\infty} = \{1, 0.8, 0.6, 0.4, 0.2, 0, 0, ...\}$. We also study an *announcement* policy in which households are informed that all interest payments can be deducted for another 15 years before the MID is removed permanently, i.e., $\{\tau_t^m\}_{t=1}^{t=\infty} = \{1, 1, 1, 1, 1, 0, 0, ...\}$. These policies together with the immediate reform are depicted in Figure 1.6a.

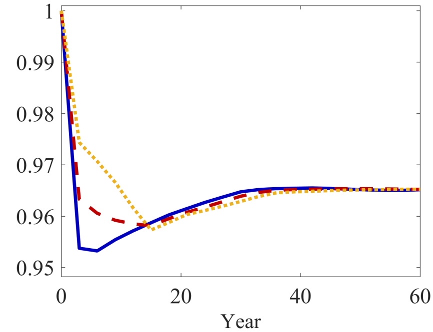
How do short-run dynamics depend on the timing of policies?

Figure 1.6 shows the short-run dynamics for the house price, the rental price, the average marginal labor income tax rate before deductions, and the bequest rate, for all three policies. The house price falls most rapidly under the immediate policy. The price fall under a given removal policy is mainly driven by changes in the housing demand of young itemizing households. As seen in the second row of Figure 1.2, young households have high LTVs and mortgage-to-earnings when they enter the housing market. As these households also tend to itemize deductions, they respond strongly to changes in the deductibility rate. Under the gradual and announcement policies, the response in housing demand is smaller due to the extended possibilities to deduct mortgage interest payments.

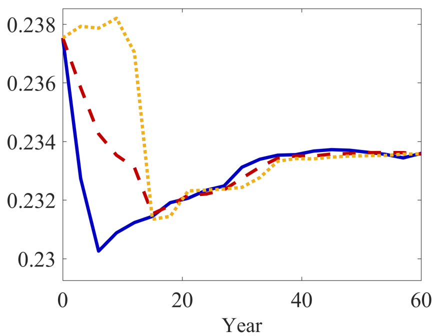
[15] For an analysis of a grandfather policy, see Appendix 1.E.



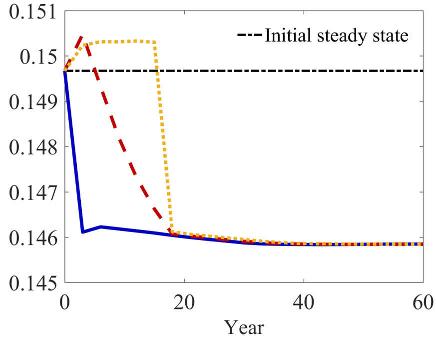
(a) Deductibility rate τ^m



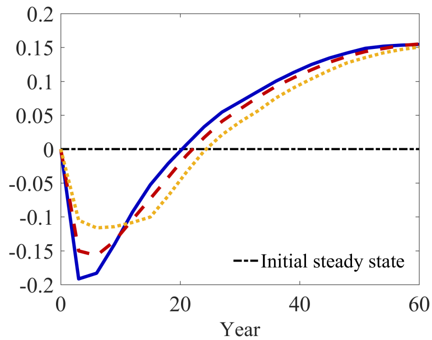
(b) House price



(c) Rental price



(d) Average marginal labor income tax rate before deductions



(e) Bequest rate γ (%)

Figure 1.6: Short-run dynamics from removing the MID, across policies
Note: Panel (a) shows how the deductibility rate is decreased under the three policy reforms. All policies are implemented unexpectedly and households have perfect foresight of the transition paths of prices, taxes, and bequests. Panels (b)-(e) show how the house price, the rental price, the average marginal tax rate before deductions, and the bequest rate behave in the short run, in response to the paths of the deductibility rate. The rental price corresponds to a three-year (one model period) cost of renting.

Although the instantaneous drop in the house price is the largest under the immediate policy, more than fifty percent of the total price fall occurs in the first transition period for the gradual and announcement policies. The higher present value of the future user cost of owning instantly results in a lower demand for owned housing, under all policies. The demand effect is reinforced by the transaction costs associated with buying and selling a house. The transaction costs restrain households from frequently re-optimizing their house size, which makes a house purchase a long-term investment.

The short-run dynamics of the rental price is fully explained by the path of house prices, as shown in equation 1.9. Under the immediate policy, the rental price closely follows the house price, whereas the rental price remains elevated for some periods under the more gradual policies.

The differences in the labor income tax levels between policies are driven by the paths of the deductibility rate and the house price. A lower mortgage deductibility rate decreases the government's tax expenditures, and allows the government to reduce the labor income tax level. On the other hand, a fall in the house price decreases the property tax payments, which worsens the government's budget. Under the immediate policy, the labor income tax level can be reduced at once. Under the gradual and announcement policies, the labor income tax rates initially increase, as the revenue from property taxes falls and the government still spends large amounts on interest deductions.

The initial drop in the bequest rate is driven by the unexpected fall in the house price, which decreases the value of collected bequests. As the fall in the house price is the largest under the immediate policy, so is the negative effect on bequests. Along the transition, the bequest rate increases as households' asset holdings become increasingly similar to those in the new steady state, where the average net worth is higher.

How do welfare effects depend on the timing of policies?

Although the less abrupt policies give households more time to adjust their allocations, we find that the immediate policy is actually preferred to those policies. As seen in Table 1.8, the immediate policy has both the highest mean CEV and is the policy with the highest share of households experiencing welfare improvements. Thus, we find that none of the policies are able to achieve a majority support or positive welfare effects on average. Even in an analysis where we consider the discounted welfare of all households that enter the economy along the transition, the average welfare effect remains negative for all policies.[16] Moreover, we cannot find a one-time cash transfer scheme that results in a Pareto improvement under any of the policies considered.

	Immediate	Gradual	Announcement
Mean CEV (%)	-0.40	-0.52	-0.52
Fraction in favor	0.39	0.35	0.27

Table 1.8: Welfare effects of households alive in the first period of the transition
Note: The fraction in favor is the fraction of households with a CEV greater than or equal to zero. For a description of CEV (%) see *Note* below Figure 1.5.

There are substantial differences in the CEV distributions across policies, as seen in Figure 1.7. Naturally, the direct effect of removing the MID is negative under all policies. The average welfare loss from this channel is dampened under the gradual and announcement reforms, which reduces the left-hand tail of the CEV distribution.

The slower fall in rental prices and house prices under the gradual and announcement policies affects both renters and homeowners. Renters prefer the immediate policy, since they benefit from a faster

[16] Specifically, the mean discounted CEV (%) would be -0.08, -0.14, and -0.16 under the immediate, gradual, and announcement policy, respectively. We discount the welfare of newborns by β^{t-1}, noting that $t = 1$ is the first period of the transition.

decline in prices. As a result, the right-hand peak of the distribution in Figure 1.7 is shifted to the left under the gradual and announcement policies. For homeowners, the accelerated fall in the house price under the immediate policy reduces the housing equity more rapidly, and the losses distributed from the rental companies are higher. The overall effect of changes in rental prices and house prices is a decrease in average welfare. Quantitatively, this negative effect is similar in magnitude under all policies.[17]

The fall in house prices also leads to a reduction in bequests during the first periods of the transition and has a negative impact on all households. This negative effect is somewhat less pronounced under the more gradual policies when the house price fall is smaller.

A lower labor income tax level benefits all households and shifts the whole CEV distribution to the right. Households benefit the most from labor income tax changes under the immediate policy, which has the lowest tax rate in the first five periods of the transition. The short-term differences in tax rates between policies have important implications for welfare and constitute a key reason why the immediate policy achieves the smallest welfare loss.

1.5.4 An MID removal after the Tax Cuts and Jobs Act

At the end of 2017, the Tax Cuts and Jobs Act (TCJA) was enacted (see, e.g., Gale et al. (2019) for a summary). In this section, we take a closer look at the welfare effects of an MID removal after incorporating some of the main changes of the tax reform. Specifically, we focus on two changes to the tax system: the near doubling of the standard deduction and the new cap on deductions for state and local income taxes and property taxes. These changes are likely to be particularly important for an MID removal. They reduce the fraction of households

[17] For a detailed account of the welfare effects under different equilibrium assumptions, see Figure 1.10 in Appendix 1.F.

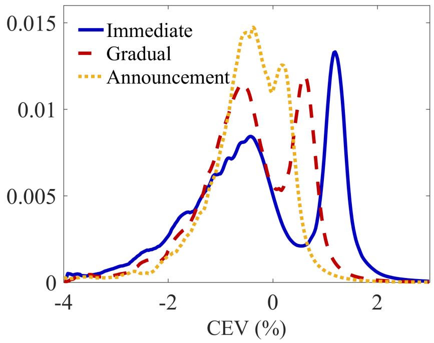


Figure 1.7: Distributions of short-run welfare effects, across policies
Note: Distributions of welfare effects of the three policies, for households alive in the first period of the transition. For a description of CEV (%) see *Note* below Figure 1.5.

that choose to itemize deductions and thus the number of households that benefit from the MID. There are other features of the fiscal reform that we have not incorporated in the model because we believe that they are unlikely to have large effects on our results.[18]

[18]There are primarily three parts of the tax reform that are related to our modeling framework that we have chosen to not incorporate. First, under the TCJA it is no longer possible to deduct interest payments for home equity lines of credit. We have no explicit role for home equity lines of credit in the model and only 5 percent of total mortgages are home equity loans in the SCF 2013 wave. Second, the cap on total mortgage interest payments that can be deducted was reduced from 1M to 750k. In our model, this change affects very few households, especially since the new cap on property tax deductions reduces the house sizes of high-income households. Finally, the TCJA reduced the tax rates and altered the thresholds for most federal income tax brackets. In the model, we calibrate the two parameters of our labor income tax function to match the average marginal tax rate in data, and the distribution of households exposed to the different statutory marginal tax rates. We do not have data for this after the new tax rates and thresholds were implemented, and it is therefore not obvious how the changes should be translated into changes of the parameters. However, with lower marginal tax rates for high-income households, the benefits of the MID are likely further reduced with the new tax schedule. As a result, the negative effects of a removal may be smaller.

We operationalize the TCJA by increasing the baseline standard deduction by a factor of 1.9 and by setting the maximum deduction for the sum of state and local income taxes and property taxes to 10,000 in 2018 dollars.[19] For simplicity, we assume that the new legislation is permanent, although these individual tax code provisions are all scheduled to expire at the end of 2025. Note that we do not require the TCJA to be tax neutral, i.e., the labor income tax level is not changed. However, we do adjust the bequest parameter γ, taking into account that the bequests left behind may change. We proceed by repeating the policy experiments in the previous section, but take as a starting point the steady state with taxes set according to the TCJA.

Table 1.9 summarizes the results of the short-run policy experiments, whereas the long-run results are provided in Appendix 1.G. For all removal policies, a majority of households are against a removal and the average CEV is negative. Quantitatively, the average welfare effects are less negative compared to our benchmark results, as the direct effect of removing the MID is reduced under the new tax code. Under the TCJA tax code, only households with considerable mortgages find it worthwhile to itemize tax deductions, resulting in an itemization rate of just 9 percent. Since removing the MID affects fewer households directly, the removal also has a more muted effect on taxes and prices. For example, the house price fall is only about half as large as under the baseline calibration. As a result, the welfare losses for homeowners are smaller, but so are the welfare gains for renters.

[19] Under prior law, the 2018 standard deduction would have been 6,500 dollars for single filers, 13,000 dollars for joint filers, and 9,550 dollars for head of household. Under the TCJA, the standard deduction is 12,000 dollars for single filers, 24,000 dollars for joint filers, and 18,000 dollars for head of household; see Gale et al. (2019).

	Immediate	Gradual	Announcement
Mean CEV (%)	-0.28	-0.30	-0.26
Fraction in favor	0.39	0.38	0.35

Table 1.9: Short-run welfare effects: Tax Cuts and Jobs Act
Note: The fraction in favor is the fraction of households with a CEV greater than or equal to zero. For a description of CEV (%) see *Note* below Figure 1.5.

1.6 Concluding remarks

A growing academic literature consistently shows that, in the long run, most American households would be better off without the MID. Much less is known about how a repeal of the MID would affect current households and, in particular, how these effects depend on the design of the removal policy. In this paper, we attempt to fill this gap by taking into account transitional dynamics and studying the welfare effects of several MID removal policies.

Our results show i) that the welfare effects of an unexpected and immediate removal policy are negative on average and less than forty percent of households benefit from the reform, and ii) that more gradual policies do not improve these outcomes. The results materialize despite our finding that 88 percent of households would prefer to be born into a world without the MID. We argue that the inclusion of mortgage-refinancing costs, which reduce the liquidity of housing wealth, and an explicit modeling of retirees, are the main reasons why we find considerably lower welfare effects as compared to the existing literature. In our analysis, we find that both aggregate and distributional welfare measures depend significantly on how the MID is removed and that households differ in their preferred policy design. More gradual policies, which give households more time to prepare for an MID removal, are successful in mitigating the losses for those who suffer the most under an immediate policy. However, a majority of households actually prefer an immediate removal with large and instantaneous equilibrium effects of lower prices and taxes.

Our analysis highlights the importance of including realistic life-cycle dynamics and key frictions to understand the welfare effects of tax policies in the housing market. To further increase our comprehension of how government policies affect households differentially, this class of heterogeneous agent models provide a promising platform. There are a number of extensions that are worthwhile considering in future work on housing tax reforms, in particular when studying a removal of the MID. First, potential demand effects on output from, e.g., lower house prices could be explored. To the extent that such changes in output can have important feedback effects into house prices, these effects are omitted from our analysis. Second, it would be interesting to explore whether a Pareto improvement can be achieved by combining the removal with more elaborate transfer schemes. In this paper, we do not find a one-time transfer scheme between winners and losers of the current generation that would make everyone better off. However, since future generations benefit from the removal, it might be possible to obtain a Pareto improvement by allowing the government to take up debt and redistribute gains from coming generations. Last, expanding the analysis by allowing house prices to be non-linear in house size may have implications for homeownership and welfare. Our analysis shows that a removal of the MID reduces the demand for larger houses, whereas more households buy smaller homes. Although we find these considerations interesting, we leave them as suggested avenues for future research.

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Appendices

1.A Equilibrium definitions

1.A.1 Stationary equilibria

Households are heterogeneous with respect to age $j \in \mathcal{J} \equiv \{1, 2, ..., J\}$, permanent earnings $z \in \mathcal{Z} \equiv \mathbb{R}_{++}$, mortgage $m \in \mathcal{M} \equiv \mathbb{R}_{+}$, owner-occupied housing $h \in \mathcal{H} \equiv \{0, \underline{\mathrm{h}}, ..., \bar{h} = \bar{s}\}$, and cash-on-hand $x \in \mathcal{X} \equiv \mathbb{R}_{++}$. Let $\mathcal{U} \equiv \mathcal{Z} \times \mathcal{M} \times \mathcal{H} \times \mathcal{X}$ be the non-deterministic state space with $\mathbf{u} \equiv (z, m, h, x)$ denoting the vector of individual states. Let $\mathbf{B}(\mathbb{R}_{++})$ and $\mathbf{B}(\mathbb{R}_{+})$ be the Borel σ-algebras on $\mathbb{R}_{++}$ and $\mathbb{R}_{+}$, respectively, and $P(\mathcal{H})$ the power set of $\mathcal{H}$, and define $\mathscr{B}(\mathcal{U}) \equiv \mathbf{B}(\mathbb{R}_{++}) \times \mathbf{B}(\mathbb{R}_{+}) \times P(\mathcal{H}) \times \mathbf{B}(\mathbb{R}_{++})$. Further, let $\mathbb{M}$ be the set of all finite measures over the measurable space $(\mathcal{U}, \mathscr{B}(\mathcal{U}))$. Then $\Phi_j(U) \in \mathbb{M}$ is a probability measure defined on subsets $U \in \mathscr{B}(\mathcal{U})$ that describes the distribution of individual states across agents of age $j \in \mathcal{J}$. Finally, denote the time-invariant fraction of the population of age $j \in \mathcal{J}$ by Π_j.

Stationary equilibrium with MID

Definition 1. A stationary recursive competitive equilibrium with MID ($\tau^m = 1$) is a collection of value functions $V_j(\mathbf{u})$ with associated policy functions $\{c_j(\mathbf{u}), s_j(\mathbf{u}), h'_j(\mathbf{u}), m'_j(\mathbf{u}),$
$\underline{b'_j}(\mathbf{u})\}$ for all j; prices $(p_h = 1, p_r)$; a quantity of total housing stock $\bar{H}$; government's total tax revenue $\overline{TR}$; a quantity of total bequests left behind $\overline{BQ}$; and a distribution of agents' states Φ_j for all j such that:

1. Given prices $(p_h = 1, p_r)$, $V_j(\mathbf{u})$ solves the Bellman equation (1.8) with the corresponding set of policy functions $\{c_j(\mathbf{u}), s_j(\mathbf{u}), h'_j(\mathbf{u}), m'_j(\mathbf{u}), b'_j(\mathbf{u})\}$ for all j.

2. Given $p_h = 1$, the rental price per unit of housing service p_r is given by equation (1.9).

3. The quantity of the total housing stock is given by the total demand for housing services[20]

$$\bar{H} = \sum_{\mathcal{J}} \Pi_j \int_U s_j(\mathbf{u}) d\Phi_j(U).$$

4. The government's net tax revenue $\overline{TR}$ is given by equation (1.12).

5. Total bequests $\overline{BQ}$ are given by equation (1.13).

6. The distribution of states Φ_j is given by the following law of motion for all $j < J$

$$\Phi_{j+1}(\mathcal{U}) = \int_U Q_j(\mathbf{u}, \mathcal{U}) d\Phi_j(U),$$

   where $Q_j : \mathcal{U} \times \mathscr{B}(\mathcal{U}) \rightarrow [0, 1]$ is a transition function that defines the probability that a household at age j transits from its current state $\mathbf{u}$ to the set $\mathcal{U}$ at age $j + 1$.

Stationary equilibrium without MID

Definition 2. A tax neutral stationary recursive competitive equilibrium without MID ($\tau^m = 0$) is a collection of value functions $V_j(\mathbf{u})$ with associated policy functions $\{c_j(\mathbf{u}), s_j(\mathbf{u}), h'_j(\mathbf{u}), m'_j(\mathbf{u}), b'_j(\mathbf{u})\}$ for all j; prices (p_h, p_r); a quantity of the total housing stock H; a parameter governing the average labor income tax level λ; a bequest parameter γ; and a distribution of agents' states Φ_j for all j such that:

[20] We assume a perfectly elastic supply of both owner-occupied housing and rental units in the initial steady state. This implies that supply always equals demand, and we thus have market clearing.

1. Given prices (p_h, p_r) and parameters (γ, λ), $V_j(\mathbf{u})$ solves the Bellman equation (1.8) with the corresponding set of policy functions $\{c_j(\mathbf{u}), s_j(\mathbf{u}), h'_j(\mathbf{u}), m'_j(\mathbf{u}), b'_j(\mathbf{u})\}$ for all j.

2. Given p_h, the rental price per unit of housing service p_r is given by equation (1.9).

3. The housing market clears:

$$H = \bar{H}$$

where $H = \sum_{\mathcal{J}} \Pi_j \int_U s_j(\mathbf{u}) d\Phi_j(U)$

and $\bar{H}$ is the housing stock from the equilibrium with MID.

4. The government's net tax revenue is the same as in the steady state with MID:

$$TR = \overline{TR}$$

where TR is given by equation (1.12)

and $\overline{TR}$ is the tax revenue from the equilibrium with MID.

5. The bequest parameter γ is the solution to

$$BQ - \overline{BQ} = \sum_{j=1}^{J-1} \Pi_j \phi_j \int_U \gamma z(\mathbf{u}) d\Phi_j(U)$$

where BQ are given by equation (1.13)

and $\overline{BQ}$ are the bequests from the equilibrium with MID.

6. Distributions of states Φ_j are given by the following law of

motion for all $j < J$

$$\Phi_{j+1}(\mathcal{U}) = \int_U Q_j(\mathbf{u}, \mathcal{U}) d\Phi_j(U),$$

1.A.2 Transitional equilibrium

Let $\Phi_{tr,jt}(U_t) \in \mathbb{M}$ be a probability measure defined on subsets $U_t \in \mathscr{B}(\mathcal{U})$ that describes the distribution of individual states across agents of age $j \in \mathcal{J}$ at time period t.

Definition 3. Given a sequence of mortgage interest deductibility parameters $\{\tau_t^m\}_{t=1}^{t=\infty}$ and initial conditions $\Phi_{tr,j1}(U_1)$ for all j, a tax neutral transitional recursive competitive equilibrium is a sequence of value functions $\{V_{jt}(\mathbf{u})\}_{t=1}^{t=\infty}$ with associated policy functions $\{c_{jt}(\mathbf{u}), s_{jt}(\mathbf{u}), h'_{jt}(\mathbf{u}), m'_{jt}(\mathbf{u}), b'_{jt}(\mathbf{u})\}_{t=1}^{t=\infty}$ for all j; a sequence of prices $\{(p_{h,t}, p_{r,t})\}_{t=1}^{t=\infty}$; a sequence of quantities of total housing demand $\{H_t\}_{t=1}^{t=\infty}$; a sequence of parameters governing the average labor income tax level $\{\lambda_t\}_{t=1}^{t=\infty}$; a sequence of bequest parameters $\{\gamma_t\}_{t=1}^{t=\infty}$; and a sequence of distributions of agents' states $\{\Phi_{tr,jt}\}_{t=1}^{t=\infty}$ for all j such that:

1. Given prices $(p_{h,t}, p_{r,t})$ and parameters (γ_t, λ_t), $V_{jt}(\mathbf{u})$ solves the Bellman equation with the corresponding set of policy functions $\{c_{jt}(\mathbf{u}), s_{jt}(\mathbf{u}), h'_{jt}(\mathbf{u}), m'_{jt}(\mathbf{u}), b'_{jt}(\mathbf{u})\}$ for all j and t.

2. Given $p_{h,t}$ and $p_{h,t+1}$, the rental price per unit of housing service is $p_{r,t}$ for all t.

3. The housing market clears:

$$H_t = \bar{H} \quad \forall t$$

$$\text{where} \quad H_t = \sum_{\mathcal{J}} \Pi_j \int_{U_t} s_{jt}(\mathbf{u}) d\Phi_{tr,jt}(U_t) \quad \forall t$$

and $\bar{H}$ is the housing stock from the equilibrium with MID.

4. The government's net tax revenue is the same as in the steady state with MID:

$$TR_t = \overline{TR} \quad \forall t$$

where TR_t is the total tax revenue in period t, $\forall t$
and $\overline{TR}$ is the tax revenue from the equilibrium with MID.

5. The bequest parameter γ_t is the solution to:

$$BQ_t - \overline{BQ} = \sum_{j=1}^{J-1} \Pi_j \phi_j \int_{U_t} \gamma_t z(\mathbf{u}) d\Phi_{tr,jt}(U_t) \quad \forall t$$

where BQ_t is the value of bequests in period t, $\forall t$
and $\overline{BQ}$ are the bequests from the equilibrium with MID.

6. Distributions of states $\Phi_{tr,jt}$ are given by the following law of motion for all $j < J$ and t:

$$\Phi_{tr,j+1,t+1}(\mathcal{U}) = \int_{U_t} Q_{tr,jt}(\mathbf{u}, \mathcal{U}) d\Phi_{tr,jt}(U_t),$$

where $Q_{tr,jt} : \mathcal{U} \times \mathscr{B}(\mathcal{U}) \to [0, 1]$ is a transition function that defines the probability that a household of age j at time t transits from its current state $\mathbf{u}$ to the set $\mathcal{U}$ at age $j + 1$ and time $t + 1$.

1.B Computational method

We discretize the state space by choosing a finite grid for permanent earnings $Z_j \equiv \{z_{j,1}, ..., z_{j,N_Z}\}$ and cash-on-hand $X \equiv \{x_1, ..., x_{N_X}\}$.[21] Permanent earnings are age specific with $N_Z = 9$ grid points. We set the number of cash-on-hand grid points N_X to 30. Moreover, we

[21] We do, however, allow households to have permanent earnings z and cash-on-hand x off grid. We linearly interpolate in cases where z and x are off grid.

take into account the concavity of the value function by letting the spacing between two grid points increase with the level of cash-on-hand. Housing is assumed to be available in discrete sizes only and we let the grid for housing be $H \equiv \{0, h_1, ..., h_{N_H}\}$ where h_1 is calibrated and $N_H = 9$.

To solve for the value and policy functions, we use the general generalization of the endogenous grid method G^2EGM by Druedahl and Jørgensen (2017). The method allows for occasionally binding constraints and non-convexities, while reaping the speed benefits associated with the traditional EGM as in Carroll (2006).

We approximate expectations to solve for the value and policy functions. The transitory earnings shocks are approximated by five Gauss-Hermite quadrature nodes, whereas the permanent earnings shocks are approximated using Markov chains. We use the method in Tauchen (1986), but allow the support for shocks to fan out over the life cycle (see, e.g., Storesletten et al. (2004)). For each age, we let the outermost grid points be $m_Z = 3$ standard deviations from the mean. For simulation purposes, we draw both shocks from their respective continuous distributions. To avoid extrapolation of permanent shocks outside the $m_Z = 3$ standard deviation bound, we force permanent income to be on the outermost grid point whenever necessary.

Similar to the traditional EGM, we use grids for the post-decision states to solve for the value and policy functions. The post-decision states in our model are bonds $b' \in \mathbb{R}_+$, mortgages $m' \in \mathcal{M} \equiv \mathbb{R}_+$, and housing $h' \in \mathcal{H}$. We force m' to be on grid whenever the household chooses a positive amount of bonds, and mortgages are not given by a constraint. For computational convenience, we let b'_y and ltv' be post-decision states instead of b' and m', respectively, where b'_y denotes bonds as a fraction of earnings and ltv' denotes loan-to-value.[22]

Let ϵ be a very small positive number. We choose a finite grid

[22]Note that both b' and m' can easily be backed-out from b'_y and ltv', for given earnings y, housing h', and house price p_h.

for bonds over earnings $B_y \equiv \{b_{y,1} = 0, b_{y,2} = \epsilon, b_{y,3}, ..., b_{y,N_B}\}$ where $N_B = 25$ and the grid points are denser at lower levels of bonds over earnings. The finite grid for loan-to-value is $LTV \equiv \{ltv_1 = 0, ltv_2 = \epsilon, ..., (1-\theta-\epsilon), (1-\theta), (1-\theta+\epsilon), ..., ltv_{N_{LTV}}\}$ where $N_{LTV} = 21$ and θ is the down-payment requirement. Between ltv_2 and $(1-\theta-\epsilon)$ spacing is linear. Spacing is also linear between $(1-\theta+\epsilon)$ and $ltv_{N_{LTV}}$. We allow policy functions for b'_y and ltv' to be off grid by using linear interpolation.

From the definition of the finite grid LTV, we can see how the alternative formulation of post-decision states is particularly convenient in the case of mortgages. First, we ensure that the loan-to-value requirement is on the discretized grid. Second, we can easily specify loan-to-value levels that are very close to the occasionally binding constraints. Both these features help facilitate more efficient and accurate solutions.

To solve for the equilibrium, we simulate $150,000$ households for J periods. When aggregating, each age group is assigned a weight Π_j, where the weight reflects the true population density in the U.S. Households are born with some initial assets. During their lives, they receive earnings shocks from continuous distributions, along with some bequests, at the beginning of each period. Households then pay taxes before they make their choices.

All policy reforms are unexpected and we adjust individual states for changes in the house price and taxes. Specifically, cash-on-hand x needs to be adjusted due to the fact that (i) the value of the house falls; (ii) the property tax payment falls; (iii) there are lower tax deductions due to changes in the MID and lower property taxes; (iv) there are changes in the tax level parameter λ; (v) there are changes in the bequest parameter γ; and (vi) there are losses incurred by rental companies. In addition, we need to adjust for changes in the loan-to-value due to a lower house price.

At any time t during the transition, new households enter the economy and replace the households that die between periods $t-1$ and t. We assume that newborns are hit by the same sequences of exogenous earnings shocks as the households they replace.

1.C Solution algorithm

1.C.1 Steady state

Solving the initial steady state with MID ($\tau^m = 1$):

1. Impose house price $p_h = 1$ and compute p_r from equation (1.9).
2. Solve the household problem recursively, and obtain the value and policy functions.
3. Simulate using optimal decision rules.
4. Use simulated values to compute the total housing stock $\bar{H}$, the government's total tax revenue $\overline{TR}$, and total bequests $\overline{BQ}$. From the simulation, we also get the distribution of agents' states Φ_j for all j.

Let λ_{init} be the parameter value of the labor income tax level in the initial steady state. Then, solving the new tax and bequest neutral steady state without MID ($\tau^m = 0$) can be divided into 2 stages. In the first stage, we solve the steady state without MID given that $\lambda = \lambda_{init}$ and $\gamma = 0$, i.e., we do not impose tax neutrality and do not consider changes in the amount of bequest:

1. Guess p_h and compute p_r.
2. Recursively solve for the value and policy functions, and simulate using optimal decision rules. Use simulated values to compute the total housing demand H.
3. Compute excess demand for housing $ED_H = H - \bar{H}$.

(a) If $|ED_H|$ is larger than some tolerance level, update p_h using bisection and return to step 1.

(b) If $|ED_H|$ is within the tolerance level, convergence in the first stage is achieved. Denote the equilibrium house price under stage 1 as $\hat{p}_h$.

In the second stage, we solve for the tax and bequest neutral steady state:

1. Guess (p_h, λ, γ), where the first guess is $p_h = \hat{p}_h + \epsilon_{p_h}$, $\lambda = \lambda_{init} + \epsilon_\lambda$, and $\gamma = 0 + \epsilon_\gamma$.

2. Given p_h, compute p_r.

3. Recursively solve for the value and policy functions, and simulate using optimal decision rules. Use simulated values to compute the total housing demand H, government's total tax revenues TR, total bequests distributed $\widehat{BQ}$, and total bequests collected BQ.

4. Compute excess demand for housing, excess government tax revenue, and the excess bequest, ED_H, $ED_{TR} = TR - \overline{TR}$, and $ED_{BQ} = (BQ - \overline{BQ}) - \widehat{BQ}$, respectively.

   (a) If $|ED_H|$, $|ED_{TR}|$, and/or $|ED_{BQ}|$ are larger than some tolerance levels, update the guess for (p_h, λ, γ) using the rule $q' = q + ED_k * \epsilon_q$ where $q \in \{p_h, \lambda, \gamma\}$ and $k = H$ if $q = p_h$, $k = TR$ if $q = \lambda$ and $k = BQ$ if $q = \gamma$. Return to step 2.

   (b) If all of $|ED_H|$, $|ED_{TR}|$, and $|ED_\gamma|$ are within the tolerance levels, convergence is achieved.

1.C.2 Transition

Let $\Phi_{init,j}$ be the distribution of households' states in the initial steady state, and let λ_{new} and γ_{new} be the equilibrium λ and γ from the tax and bequest neutral steady state without MID. Further, let t denote the transition period, and assume that the economy is in the new steady state in $t = T+1$. Choose T large enough so that by increasing T the transition path is unaltered.[23] The solution algorithm for the transitional equilibrium can be described in two stages. In the first stage, we solve for the transitional equilibrium assuming $\lambda_t = \lambda_{new}$ and $\gamma_t = \gamma_{new}$ $\forall t \in \mathcal{T} \equiv \{1, ..., T\}$:

1. Guess $\{p_{h,t}\}_{t=1}^{t=T}$ and compute $\{p_{r,t}\}_{t=1}^{t=T}$.

2. Recursively solve for the value and policy functions for all ages $j \in \mathcal{J}$ and time periods $t \in \mathcal{T}$. To solve for value and policy functions at time period $t = T$, assume that the value and policy functions in $t = T + 1$ are those from the new steady state with neutrality.

3. Given the price $p_{h,1}$ and parameters γ_1 and λ_1, for each $j \in \mathcal{J}$, adjust the initial individual states such that the initial distribution $\Phi_{init,j}$ reflects unexpected changes in the house price, the tax level, and bequests from the initial steady state.

4. Simulate using the adjusted initial distribution and optimal decision rules. Use simulated values to compute the sequence of total housing demand $\{H\}_{t=1}^{t=T}$.

5. Compute the sequence of excess demand for housing $\{ED_{H,t}\}_{t=1}^{t=T}$, and the Euclidean norm of this sequence.

    (a) If the norm is larger than some tolerance level, update $\{p_{h,t}\}_{t=1}^{t=T}$ using the rule $p'_{h,t} = p_{h,t} + ED_{H_t} * \epsilon_{p_h}$ for all

[23] We set $T = J + 5$.

$t \in \mathcal{T}$ and return to step 1.

(b) If the norm is within the tolerance level, convergence in the first stage is achieved. Denote the equilibrium house prices under stage 1 $\hat{p}_{h,t}$ for all $t \in \mathcal{T}$.

In the second stage, we solve for the tax neutral transitional equilibrium:

1. Guess $\{(p_{h,t}, \lambda_t, \gamma_t)\}_{t=1}^{t=T}$, where the first guess is $p_{h,t} = \hat{p}_{h,t}$, $\lambda_t = \lambda_{new}$, and $\gamma_t = \gamma_{new}$ for all $t \in \mathcal{T}$.

2. Given $\{p_{h,t}\}_{t=1}^{t=T}$, compute $\{p_{r,t}\}_{t=1}^{t=T}$.

3. Recursively solve for the value and policy functions for all ages and time periods, adjust the initial individual states such that the initial distribution $\Phi_{init,j}$ reflects unexpected changes in the house price, the tax level and bequests from the initial steady state, and simulate using the adjusted initial distribution and optimal decision rules. Use simulated values to compute the sequences of total housing demand $\{H\}_{t=1}^{t=T}$, the government's total tax revenues $\{TR\}_{t=1}^{t=T}$, the total bequests distributed $\{\widehat{BQ}\}_{t=1}^{t=T}$, and the total bequests collected $\{BQ\}_{t=1}^{t=T}$.

4. Compute the sequences of excess demand for housing, excess government tax revenue, and excess bequests, $\{ED_{H,t}\}_{t=1}^{t=T}$, $\{ED_{TR,t}\}_{t=1}^{t=T}$, and $\{ED_{BQ,t}\}_{t=1}^{t=T}$, respectively. Compute the Euclidean norm of all three sequences.

   (a) If the norm of either sequence is larger than some tolerance level, update the guess $\{(p_{h,t}, \lambda_t, \gamma_t)\}_{t=1}^{t=T}$ using the rule $q' = q + ED_k * \epsilon_q$ for all $t \in \mathcal{T}$, where $q \in \{p_{h,t}, \lambda_t, \gamma_t\}$ and $k = H_t$ if $q = p_{h,t}$, $k = TR_t$ if $q = \lambda_t$, and $k = BQ_t$ if $q = \gamma_t$. Return to step 2.

   (b) If all norms are within the tolerance levels, convergence is achieved.

1.D Labor income process

1.D.1 Data sample

Equations (1.18) and (1.19) are estimated using PSID data for the survey years 1970 to 1992. Following Cocco et al. (2005), we drop households where the head was i) a nonrespondent, ii) part of the Survey of Economic Opportunities subsample, iii) disabled or retired, iv) a student, or v) a housewife. Due to few female headed households, we exclusively focus on households with male heads.

In line with Guvenen (2009), we further restrict the sample by only keeping households for which i) earnings are strictly positive, ii) annual hours worked by head are between 520 (10 hours per week) and 5110 (14 hours a day, everyday), iii) the head's average hourly wage is between \$2 and \$400 (inclusive) in 1993 dollars, where we adjust the bounds backwards using the growth rate in average weekly earnings from "Current Employment Statistics" published by the Bureau of Labor Statistics. Series ID: CES0500000030. iv) the head is between 20 and 64 years old, and v) the head appears in the sample in at least 15 out of 23 possible survey years.

1.D.2 Estimation

In order to simulate the exogenous earnings process according to equations (1.18) and (1.19), we estimate the deterministic earnings profile $g(j)$ and the variances of the fixed-effect component σ_α^2, the permanent shock σ_η^2, and the transitory shock σ_ν^2. Estimating the deterministic wage component $g(j)$ is done in two steps. First, we estimate it on an annual basis, and then we convert it to suit the model period length of three years.

Step 1: Using the yearly observations in the data, we estimate a yearly version of the deterministic component. That is, we estimate

$g_{annual}(age)$, where $age \in \{20, 21, ..., 64\}$. We regress $\log(y_i)$ on dummies for age (not including the youngest age), marital status, family composition (number of family members besides head and, potentially, wife), and a dummy for whether the agent has a college education or not. We control for household fixed effects by running a linear fixed effect regression. We fit a third-order polynomial to the predicted values of this regression, which gives us the estimate of the *annual* deterministic earnings profile $\hat{g}_{annual}(age)$.

Step 2: We convert annual estimates to three-year periods as follows

$$\hat{g}(j) = \hat{g}_{annual}(j * 3 + 21) \quad \text{for } j \in [1, J_{ret}]. \tag{1.21}$$

Equation (1.21) states that the deterministic earnings in period $j = 1$ are the annual deterministic earnings at adult age 24 and the earnings in period $j = J_{ret}$ are the annual earnings at adult age 63. As such, the deterministic earnings in period j are equal to those of the middle adult age that period j is assumed to represent.

With an estimate of the deterministic earnings profile at hand, the variances of the transitory (σ_ν^2) and permanent (σ_η^2) shocks are estimated in a similar fashion as in Carroll and Samwick (1997). Define $\log(y^*_{ij})$ as the logarithm of earnings less the household fixed component and the deterministic earnings path

$$\begin{aligned} \log(y^*_{ij}) &\equiv \log(y_{ij}) - \hat{\alpha}_i - \tilde{g}(j) \\ &= n_{ij} + \nu_{ij} \qquad \text{for } j \in [1, J_{ret}], \end{aligned}$$

where the equality follows from equation (1.18). Since we have three-year periods in the model, we define $\log(y_{ij})$ as the sum of earnings from the three adult ages to which the model period corresponds. For example, $\log(y_{i1}) = \log(\sum_{age=23}^{25} y_{i,age}^{annual})$. Similarly, $\tilde{g}(j)$ is defined as the sum of the annual deterministic earnings components, for example $\tilde{g}(1) = \log\left(\sum_{age=23}^{25} \exp(\hat{g}_{annual}(age))\right)$. Next, define household i's

d-period difference in $\log(y^*_{ij})$ as

$$\begin{aligned} r_{id} &\equiv \log(y^*_{i,j+d}) - \log(y^*_{ij}) \\ &= n_{i,j+d} + \nu_{i,j+d} - n_{ij} - \nu_{i,j} \\ &= n_{i,j+1} + n_{i,j+2} + ... + n_{i,j+d} + \nu_{i,j+d} - \nu_{i,j}. \end{aligned}$$

In the last step, we recursively apply equation (1.19). Using that the transitory and permanent shocks are i.i.d., it follows that

$$\begin{aligned} \mathrm{Var}(r_{id}) &= \mathrm{Var}(n_{i,j+1}) + \mathrm{Var}(n_{i,j+2}) + ... + \mathrm{Var}(n_{i,j+d}) \\ &\quad + \mathrm{Var}(\nu_{i,j+d}) + \mathrm{Var}(\nu_{i,j}) \\ &= d\,\sigma^2_\eta + 2\,\sigma^2_\nu. \end{aligned}$$

We estimate these variances by running an OLS regression of $\mathrm{Var}(r_{id}) = r^2_{id}$ on d and a constant term. Then, the coefficient of d is our estimate of the variance of the permanent shock, whereas the constant term divided by two is our estimate of the variance of the transitory shock.

Finally, the estimate of σ^2_α is the residual variance in period $j = 1$ as follows

$$\hat{\sigma}^2_\alpha = \mathrm{Var}\left(\log(y_{i1}) - \tilde{g}(1)\right) - \hat{\sigma}^2_\eta - \hat{\sigma}^2_\nu.$$

1.D.3 Variable definitions

Age of head is constructed by taking the first observed age and then adding the number of years between a given survey year and the first survey in which the individual was observed. This is to avoid non-changes and two-year jumps in the age variable between two consecutive survey years. The variable name of age is V20651 in the 1992 PSID survey.

CPI is taken from the BLS. We use the historical CPI for all urban consumers (CPI-U), U.S. city average, all items.

Family composition is the number of family members besides head and, potentially, wife. We define it as family size less adults. Family size is the number of members in the family unit at the time of an interview. Adults are defined as the number of major adults (head and wife only). The variable names are V20398 and V20397 in the 1992 PSID survey for family size and adults, respectively.

Head's education is divided into two groups: households with a college degree and households with no college degree. Between 1970 to 1990, we define the education groups by using the categorical groups defined in the PSID. For example, in the 1990 survey we use the variable name V18898, and define that no college consists of levels 1 to 6, and college comprises levels 7 and 8. After 1990, we use a variable for years of completed education (variable name V21504 in 1992 survey). Then, no college households comprise levels 0 to 15 and households with a college degree comprise levels 16 and 17. We drop observations where individuals have no appropriate answer (NA or don't know) and individuals who before the 1984 survey answered "Could not read or write; DK grade and could not read or write".

Head's annual labor hours are the total annual work hours on all jobs including overtime. The variable name is V20344 in the 1992 PSID survey.

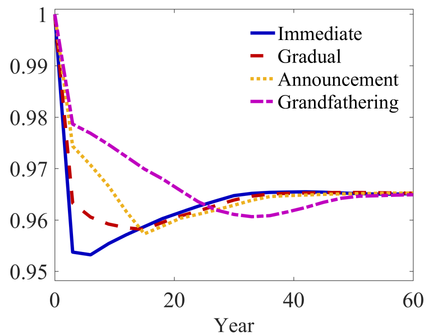
Head's average hourly wage is computed as the head's wage divided by the head's annual labor hours.

Household earnings y_{ij} are the sum of labor income for both head and wife. Earnings are deflated with the CPI using 1992 as the base year. Labor income is defined as the sum of salary income, bonuses, overtime, commissions, the labor part of farm, business, market gardening, roomers and boarders income, and income from professional practice or trade. The variable names are V21484 and V20436 in the 1992 PSID survey for head and wife, respectively.

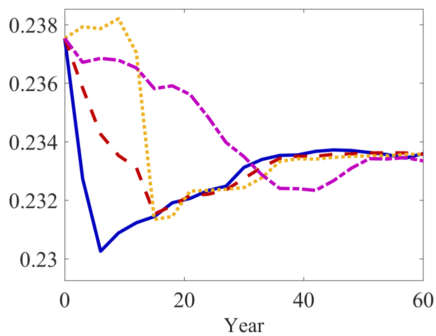
The maximum allowable benefit during retirement, B^{max} in equation (1.20), is computed using data from the Social Security Administration (SSA). Specifically, we use the maximum monthly benefit level that was available for a person retiring at age 66 in 1992 ($1,113) and multiply it by twelve to get a yearly benefit level. We adjust the yearly level for the difference in the SSA's average wage per worker in 1992 ($22,002) and the average earnings in the model.

1.E A grandfather policy

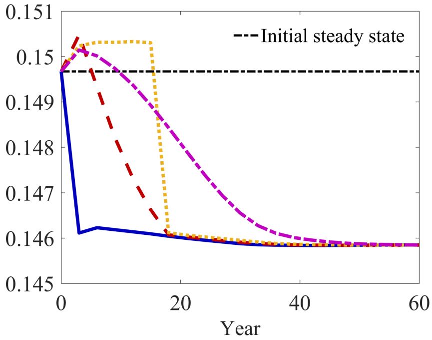
To investigate the effects of a removal policy in which we discriminate between cohorts, we study the effects of a policy where new households are not allowed to deduct mortgage interest payments, while existing households can continue to do so. We refer to this policy as the *grandfather* policy. Figure 1.8 shows the transition paths for the house price, the rental price, the average marginal tax rate, and the bequest parameter.



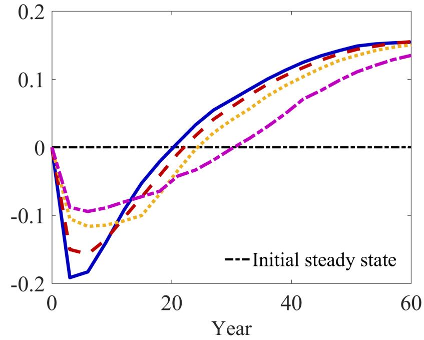
(a) House price



(b) Rental price



(c) Average marginal labor income tax rate before deductions



(d) Bequest rate γ (%)

Figure 1.8: Short-run dynamics from removing the MID, across policies
Note: All policies are implemented unexpectedly and households have perfect foresight of the transition paths. The respective panels show how the house price, the rental price, the average marginal tax rate before deductions, and the bequest rate behave in the short run, in response to the changes in the deductibility rate. The rental price corresponds to a three-year (one model period) cost of renting.

Naturally, the convergence for the grandfather policy is slower than for the alternative policies. There is also a smaller immediate fall in the house price, as only the households that enter the economy are directly affected by the MID removal. The slower fall in the house price leads to a correspondingly slower fall in the rental price. Under the grandfather policy the labor income tax rate increases initially, as the government still spends large amounts on interest deductions and the revenue from property taxes falls. As new cohorts replace older cohorts, the labor income tax level slowly declines towards the lower level of the new steady state. The value of bequests falls immediately under this policy as well, since the house price decreases. Over time, this amount slowly converges to the new steady state.

Table 1.10 presents the average CEV, and the fraction in favor, for the four policies. The grandfather policy is able to limit the welfare losses quite substantially for many homeowners, which leads to an average welfare effect close to that of the immediate policy. However, the fraction of households with a welfare gain is still low. The reason for this low support is that a significant share of renters are not in favor of the reform.

	Immediate	Gradual	Announcement	Grandfather
Mean CEV (%)	-0.40	-0.52	-0.52	-0.38
Fraction in favor	0.39	0.35	0.27	0.31

Table 1.10: Welfare effects for households alive in the first period of the transition

Note: The fraction in favor is the fraction of households with a CEV greater than or equal to zero. For a description of CEV (%), see *Note* below Figure 1.5.

Figure 1.9 displays the distribution of CEV for the four policies. Compared to the other policies, the grandfather policy has a higher house price, and a relatively high rental price and taxes for most of the transition. All these effects contribute to the lower welfare of renters, and combined with the initial drop in bequests, pushing some of these households into negative CEV territory. Similar to the other policies, most homeowners experience welfare losses from the grandfather reform. Homeowners are negatively affected by the fall in the house price and the instantaneous increase in the labor income tax level and fall in the bequest rate. However, since they can still deduct mortgage interest payments, their welfare losses are limited, especially for households with high earnings and high LTV-ratios.

Overall, the analysis of the welfare effects of the grandfather policy is similar to that of other more gradual policies. By removing the MID slowly, the welfare distribution is compressed. The households who lose the most from a repeal of the MID realize smaller welfare losses, and the households who benefit the most experience smaller welfare gains.

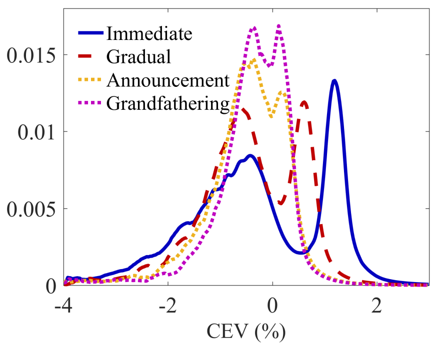
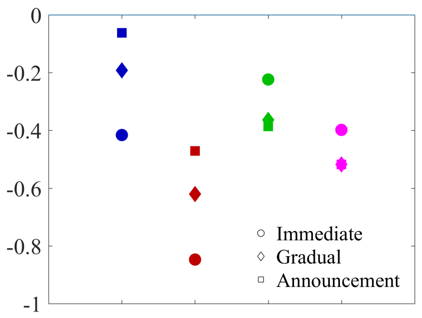


Figure 1.9: Distributions of short-run welfare effects across policies, including grandfathering

Note: Distributions of welfare effects for all policies, for households alive in the first period of the transition. For a description of CEV (%) see *Note* below Figure 1.5.

1.F Welfare effects: equilibrium assumptions



Rental and house prices adjust	-	✓	✓	✓
Tax neutrality	-	-	✓	✓
Bequests adjust	-	-	-	✓

Figure 1.10: Short-run welfare effects under different equilibrium assumptions

Note: The first column shows the mean CEV for those alive in the first period of the transition, when we only consider the direct effect of removing the MID. We account for rental companies' losses in the first period of the transition when we allow for prices to change. For a description of CEV (%) see *Note* below Figure 1.5.

1.G Tax Cuts and Jobs Act: long-run results

	Baseline			Tax Cuts and Jobs Act			Tax Cuts and Jobs Act, no cap		
	MID	No MID	Difference (%)	MID	No MID	Difference (%)	MID	No MID	Difference (%)
House price	1	0.965	-3.47	0.988	0.969	-1.85	0.997	0.975	-2.13
Rental price	0.238	0.234	-1.66	0.236	0.234	-0.88	0.237	0.235	-1.02
Homeownership rate	0.70	0.71	1.88	0.67	0.71	5.71	0.65	0.70	6.96
Fraction ever-owner	0.88	0.89	1.59	0.88	0.89	1.60	0.87	0.88	2.02
Mean owned house size	215	211	-2.15	215	211	-1.67	217	212	-2.46
Mean LTV	0.36	0.31	-12.09	0.31	0.31	0.73	0.30	0.31	1.15
Mean mortgage	74	60	-19.29	63	59	-5.43	64	59	-6.83
Mean bond holdings	20.6	21	1.81	20.9	21.3	1.85	20.6	21.3	3.40
Mean marginal tax rate	0.150	0.146	-2.59	0.150	0.149	-0.16	0.150	0.149	-0.65
Mean bequest collected	152	158	3.57	156	159	1.77	156	159	2.15
Itemization rate	0.53	0.19	-64.50	0.09	0	-100	0.12	0.02	-79.99

Table 1.11: Long-run effects on prices and aggregates of removing the MID, baseline versus Tax Cuts and Jobs Act

Note: The table shows steady-state results based on three different initial tax systems. The first tax system called "Baseline" simply reiterates the results from Table 1.4. In the "Tax Cuts and Jobs Act", we multiply the baseline standard deduction by 1.9, and the maximum deductions for the sum of state and local income taxes and property taxes are set to 10,000 in 2018 dollars. In the last tax system, we multiply the baseline standard deduction by 1.9, but there is no change in the cap. The first column within each of these tax systems shows prices and aggregate measures in the initial steady state with MID, whereas the second column shows the corresponding values in the steady state without MID. The rental price corresponds to a three-year (one model period) cost of renting. "Fraction ever-owner" is the fraction of households that own a house at some point during their life. The mean house size, LTV, and the mortgage level are conditional on owning. The mean owned house size, mortgage, bond holdings, and bequest collected are in 1000's of 2013 dollars. The mean marginal tax rate is gross of deductions.

Chapter 2

Optimal property taxation*

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2.1 Introduction

Residential property taxation is a potential source of substantial revenue for governments in many countries. Many economists are of the view that residential property should be taxed much more than it currently is.[1] They worry that households save too much in housing at the expense of other forms of capital which could increase overall earnings and consumption. Still, the tax continues to be low in most countries.

Despite the call among economists to increase property taxes, research on the subject is largely missing from the vast literature on optimal taxation.[2] This is unfortunate, as the extent to which housing should be taxed is not easily inferred from the existing literature. On the one hand, housing provides housing services and is thus similar to consumption. On the other hand, housing is also an asset and hence shares similarities with capital. Moreover, housing has some special features: houses can either be owned or rented; there are large adjustment costs when buying and selling houses; and, importantly, although it is a valuable asset for households, it does not add to the stock of productive capital that affects the wage level and the interest rate.

In this paper, I study the optimal tax on residential property to fill this gap in the literature. To this end, I first consider the optimal long-run policy by comparing the lifetime welfare of newborns across

[1] For example, before the 2014 general election in Sweden, a group of leading Swedish economists compiled a list of proposals that they believed most economists would agree on (see Ekonomistas (2014)). One of these suggestions was to increase the tax on residential property.

[2] One notable exception is the work by Eerola and Määttänen (2013) and below I discuss how my paper relates to theirs. A list of key papers on the more general topic of optimal taxation includes, but is not limited to, Summers (1981), Auerbach et al. (1983), Judd (1985), Chamley (1986), Aiyagari (1995), İmrohoroğlu (1998), Atkeson et al. (1999), Domeij and Heathcote (2004), Conesa et al. (2009), and Straub and Werning (2020).

steady states. I complement that analysis by studying the optimal one-time policy change in the short run, taking into account the welfare effects of today's generations.[3] To keep the analysis tractable, I follow a standard assumption in the literature and assume that taxes are proportional.

The tax policies in this paper are revenue neutral. Whenever the property tax changes, the capital income tax rate adjusts to keep government expenditures constant. Thus, there are important trade-offs between the cost of property taxation and the capital income tax. In the long run, the property tax mainly distorts the intratemporal decision between housing and non-housing consumption. A higher property tax reduces the consumption of housing, which is negative for welfare. In contrast, the capital income tax chiefly distorts the intertemporal decision, as it affects the price of consumption today versus the future. A higher capital income tax is unappealing as it decreases households' deposit savings and thus capital and wages in the economy.

The short run is more complicated. First, households have already made long-term housing decisions. Large adjustment costs of selling and buying houses make households' choices less elastic. Thus, in terms of efficiency, it may be desirable to tax property. At the same time, a higher property tax may also lead to significant individual welfare losses as households are locked into house sizes that are not optimal in their view. Second, capital is also a good candidate to tax for efficiency reasons as it is largely predetermined in the short run.

Two main results follow from my quantitative analysis. First, if a social planner can choose a property tax without caring about current

[3]It would be computationally infeasible to allow for fully time-varying optimal policies. All policies are assumed to be credible and implemented unexpectedly. Similar assumptions are made in, e.g., Domeij and Heathcote (2004), Bakış et al. (2015), and Krueger and Ludwig (2016) who study optimal capital taxation, optimal progressivity of the income distribution, and the optimal provision of social insurance, respectively.

generations or the transition to the new economy, the property tax should be almost five times as high as today's level of one percent. The corresponding optimal capital income tax is close to zero, but slightly negative, and is much lower than the current level of 36 percent. I show that this result is broadly in line with the theoretical predictions of a Chamley (1986) model adapted to include housing in a simplified and tractable manner.

On average, newborns benefit substantially from a move to the optimal steady state. In the benchmark model, the welfare effect is equivalent to an average increase in the initial steady-state consumption of 3.9 percent every period. This result does, however, mask important heterogeneity. In particular, I find that the optimal property tax is falling with the labor productivity of newborns. For instance, the average welfare of newborns in the top quintile of labor productivity is highest when the property tax is 3.7 percent, whereas the average welfare of newborns in the bottom quintile is maximized at a property tax level that is more than forty percent higher. Due to the presence of borrowing constraints, low-productivity households benefit more than other households from a higher capital stock. Crucially, a higher wage level, as a result of more capital, pushes these households away from the constraint. As I will show, high-productivity households, which usually become homeowners when they are young, benefit less from a lower capital income tax. They earn an excess return on their housing asset as long as the capital income tax is positive.

The second main result is that current generations want to keep tax rates relatively close to today's levels. In terms of the benchmark model, the optimal property tax rate in the short run is 0.7 percent, which implies a capital income tax of 40 percent. The welfare gain of a reduced property tax is small. In contrast, the short-run welfare costs of setting the property tax rate at its long-run optimal level are substantial on average. In fact, I find that a social planner who also values the welfare of future generations of newborns only finds it optimal to set the property tax at the long-run optimal level if the social discount rate is significantly lower than the private discount rate.

Although the optimal property tax is considerably lower in the short run as compared to the long run, it is still positive. This result is seemingly at odds with a well-known result in the literature on optimal taxation, namely that capital income should be taxed 100 percent at the time of a policy change. With the assumption of revenue neutrality, this would leave no room for additional taxes on property. There are several reasons why this result does not hold here. First, I only consider one-time changes in the property tax level and capital is only predetermined in the first period. Second, and perhaps more importantly, in a housing model, the cost of taxing capital is higher as households have access to housing as an alternative savings vehicle (Eerola and Määttänen, 2013). Third, housing is also somewhat inelastic due to lumpy transaction costs. Finally, households are heterogeneous. Thus, the welfare consequences differ across the distribution of households. For example, I find that retirees and owners of smaller houses generally want a lower property tax, whereas newborns and renters tend to be better off with a property tax level above the current levels.

The quantitative analysis is carried out using a model that includes four types of agents, namely, heterogeneous households, a representative production firm, a financial intermediary, and a government. Households enter the economy with unequal amounts of initial assets, face uncertain labor productivity during their working age, and are subject to an age-dependent probability of dying. They derive utility from non-housing consumption, housing services, and from leaving bequests. Housing services can either be obtained by renting from a financial intermediary or by owning a house. Housing purchases are considered to be long-term investments due to lumpy transaction costs of buying and selling houses. Households can thus save by investing in deposits or by building up housing equity. Borrowing is limited to homeowners and they have to adhere to a loan-to-value constraint. Proportional taxes decrease households' disposable income and are levied on labor income, capital income, and housing.

A representative firm produces goods using labor and capital as input, where labor is supplied inelastically by households and capital is borrowed from a financial intermediary. The intermediary also provides homeowners with mortgages and rent out housing services to tenants. Its operations are financed by households' deposit savings. The government operates a pay-as-you-go social security system, collects and distributes bequests, and taxes households and the financial intermediary to fund government expenditures. In the benchmark model, the interest rate adjusts to clear the capital market, the wage level and the price of rental housing are endogenous, and the house price is constant as aggregate housing is assumed to be perfectly elastic.

I test the sensitivity of my main results along four important dimensions. The general results are relatively robust to these tests, both qualitatively and quantitatively. First, I double the intertemporal elasticity of substitution (IES) from 0.5 to 1 as a higher IES should increase the cost of a non-zero tax on capital income. Second, I assume that the planner does not want any redistribution across households. Specifically, I apply so-called Negishi weights and weigh the welfare effect of each household by the inverse of its marginal utility of consumption.[4] Third, I decrease the elasticity of housing supply and allow for endogenous changes in housing prices. Finally, I test if the short-run results are sensitive to the initial property tax rate. Interestingly, in an economy with taxes set according to the

[4]The Negishi weights, after Negishi (1960), effectively equalize the marginal benefit of an extra dollar of income across households. It is a common approach in climate economics to avoid that optimal policy involves large transfers from rich to poor countries; see, e.g., Nordhaus and Yang (1996).

long-run optimal rates, the short-run optimal policy for households alive at the time of a policy change would be to revert the tax rates to current levels.

To the best of my knowledge, Eerola and Määttänen (2013) is the only other paper that has studied optimal property taxation in a dynamic framework.[5] Their paper differs from my work in two important ways. First, the economy in my model is populated by heterogeneous agents. This allows me to carefully analyze the distributional effects of property taxation which is not possible in their representative-agent framework.[6] Second, they study an optimal tax on the return to housing, whereas this paper studies a tax on the house value.

Overall, my findings suggest that the apparent disconnect between the view of economists and what we see in reality can be understood by differences in what is optimal for newborns in the long run and what is optimal for current generations. A key policy implication is that any policy recommendation should take short-run welfare considerations seriously.

The rest of the paper is organized as follows. To gain some intuition for my quantitative results, I study the theoretical implications of adding housing and a property tax to the Chamley (1986) model in Section 2.2. In Section 2.3, I present the quantitative model. The calibration of this model is then discussed in Section 2.4. In Section 2.5, I show and discuss the quantitative results and I go through a series of sensitivity analyses. Finally, I provide some concluding remarks in Section 2.6.

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[5]Nakajima (2019) studies optimal capital income taxation in a model with housing, but takes as given the property tax policies.

[6]Their study also differs along other dimensions. For example, there are no transaction costs of buying and selling housing and there is no tenure decision. They do, however, allow for time-varying policies and elastic labor supply.

2.2 Property taxation in the Chamley (1986) model

An important result in the literature on optimal taxation is the so-called Chamley-Judd result, after Chamley (1986) and Judd (1985). According to the Chamley-Judd result, the capital income tax should be zero in the long run.[7] A popular intuition for this finding is that a positive tax on capital income in the long run works as an ever-increasing tax on consumption, which cannot be optimal (see Judd (1999)).[8]

In this paper, I study optimal property taxation, where I keep government expenditures fixed by adjusting the capital income tax. To develop an intuition for later results, I add the concept of housing and property taxation to the discrete-time version of the Chamley model presented in Atkeson et al. (1999).[9] Specifically, I separate consumption into non-housing consumption and consumption of housing services, and I allow for a tax on housing services rather than labor income. To simplify the exposition, I abstract from labor income, except when I discuss results in an overlapping-generations (henceforth

[7]Straub and Werning (2020) show that this result does not necessarily follow from the models in Chamley (1986) and Judd (1985). For example, the Judd (1985) model would entail positive capital income taxation in the long run if the intertemporal elasticity of substitution is below or equal to one. The critique against the Chamley (1986) model is less strong, and Straub and Werning (2020) show that with additively separable utility, the zero-tax result also applies to models with an intertemporal elasticity below or equal to one. However, for this to hold, the upper bounds on capital income taxes must be slack in the long run.

[8]Straub and Werning (2020) show that this argument does not hold if the initial government debt is sufficiently large. When government expenditures are high, it is beneficial to tax capital income to alleviate the efficiency costs of taxing labor income. With upper bounds on capital income taxes, it may be optimal to tax capital even in the long run.

[9]Importantly, this version of the Chamley model is not subject to the critique in Straub and Werning (2020) as it assumes an additively separable utility function and bounds on the capital income tax are only imposed in the first period.

OLG) model. This simplification is not as stark as it may first appear. In fact, all results still hold if I allow for an endogenous labor supply and an additively-separable disutility of labor.

In line with the original Chamley-Judd result, I find that the capital income tax rate should be zero in the long run and that the property tax should cover government expenditures. However, for this result to hold in an OLG model, I need to place certain restrictions on the utility functions. Furthermore, I argue that there is a need to move beyond the theoretical models presented in this section. In particular, there are important features of housing that are not present in the theoretical framework.

2.2.1 Representative agent

Assume that there is a representative household that lives forever and has the discount factor $\beta < 1$. The expected discounted utility is given by

$$\sum_{t=0}^{\infty} \beta^t U(c_t, s_t), \tag{2.1}$$

where c_t is non-housing consumption and s_t is housing services in period t. Households maximize (2.1) subject to a budget constraint

$$\sum_{t=0}^{\infty} p_t \left(c_t + (1+\tau_t^h) s_t + k_{t+1} \right) = \sum_{t=0}^{\infty} p_t (1+\bar{r}_t) k_t, \tag{2.2}$$

with $k_0 > 0$. The price level in period t is p_t, and I normalize prices in period zero to 1. Similar to the benchmark model in Section 2.3, I assume that the housing supply is perfectly elastic, which implies that the pre-tax price of c_t and s_t is the same. The property tax in period t is τ_t^h, whereas k_t is capital at the start of the period and k_{t+1} are savings in capital from period t to period $t+1$. The after-tax return on savings in capital is $\bar{r}_t = (1 - \tau_t^k)(R_t - \delta^k)$, where τ_t^k is the capital income tax at time t, R_t is the rental price of capital at time t, and δ^k is the depreciation rate of capital.

The household chooses c_t, s_t, and k_{t+1} and the first-order conditions of the household problem are

$$\beta^t U_{ct} = \lambda p_t \tag{2.3}$$

$$\beta^t U_{st} = \lambda p_t (1 + \tau_t^h) \tag{2.4}$$

$$\lambda p_t = \lambda p_{t+1}(1 + \bar{r}_{t+1}), \tag{2.5}$$

where λ is the Lagrange multiplier on the budget constraint (2.2), and U_{ct} and U_{st} are the derivatives of the utility function with respect to c_t and s_t, respectively. The household's Euler equation is derived by substituting (2.3) into (2.5):

$$U_{ct} = \beta(1 + \bar{r}_{t+1}) U_{c,t+1}. \tag{2.6}$$

A representative firm produces output goods $y_t = F(k_t)$ using capital k_t as input. The firm's maximization problem is

$$\max_{k_t} F(k_t) - R_t k_t. \tag{2.7}$$

The firm's first-order condition with respect to capital implies

$$F_{kt} = R_t, \tag{2.8}$$

where F_{kt} is the derivative of $F(k_t)$ with respect to k_t. The government's revenues from taxing housing and capital income are spent on government expenditures g, which are assumed to be fixed throughout. Formally, the government budget constraint is

$$\sum_{t=0}^{\infty} p_t g = \sum_{t=0}^{\infty} p_t \left(\tau_t^h s_t + \tau_t^k (R_t - \delta^k) k_t \right).$$

Finally, there is a resource constraint which must hold every period

$$c_t + s_t + k_{t+1} + g = F(k_t) + (1 - \delta^k)k_t.$$

A competitive equilibrium can be fully characterized by the resource constraint and an implementability constraint. The implementability constraint is the household budget constraint (2.2), where I substitute for the first-order conditions of the household (2.3)-(2.5) and the first-order condition of the firm (2.8), i.e.,

$$\sum_{t=0}^{\infty} \beta^t (U_{ct}c_t + U_{st}s_t) = U_{c0}(1 + \bar{r}_0)k_0,$$

where $\bar{r}_0 = (1 - \tau_0^k)(F_{k0} - \delta^k)$ and τ_0^k is given.

Assume that the government can perfectly commit to any sequence of tax rates τ_t^h and τ_t^k for all time periods t. Assume further that the government needs to choose policies that are compatible with a competitive equilibrium. Denote the social welfare function in period t as

$$W(c_t, s_t, \mu) = U(c_t, s_t) + \mu(U_{ct}c_t + U_{st}s_t),$$

where μ is the multiplier on the implementability constraint. Then the Ramsey allocation problem can be summarized as follows

$$\max_{c_t, s_t, k_{t+1}} \sum_{t=0}^{\infty} \beta^t W(c_t, s_t, \mu) - \mu U_{c0}(1 + \bar{r}_0)k_0 \\ + \chi_t \left(F(k_t) + (1 - \delta^k)k_t - c_t - s_t - g - k_{t+1} \right),$$

where χ_t is the multiplier on the resource constraint in period t. The first-order conditions yield

$$\frac{W_{ct}}{W_{st}} = 1 \tag{2.9}$$

$$W_{ct} = \beta W_{c,t+1}\left(F_{k,t+1} + 1 - \delta^k\right) \qquad \text{for } t \geq 1 \tag{2.10}$$

$$W_{c0} = \beta W_{c1}\left(F_{k1} + 1 - \delta^k\right) + \mu U_{cc0}(1+\bar{r}_0)k_0 \quad \text{for } t = 0. \tag{2.11}$$

Equation (2.10) is key to the Chamley (1986) result on zero capital income taxation in the long run. Since the Ramsey equilibrium is a competitive equilibrium, both the intertemporal condition for the planner (2.10) and the Euler equation (2.6) must hold. Suppose that the economy reaches a steady state with $(c_t, s_t, k_t) = (c, s, k)$ for all t, such that $W_{ct} = W_{c,t+1}$ and $U_{ct} = U_{c,t+1}$. It then follows that the Euler equation (2.6) is equal to the intertemporal optimality condition of the planner (2.10) if and only if $(1 - \tau_t^k)(F_{k,t+1} - \delta^k)$ is equal to $F_{k,t+1} - \delta^k$. In turn, this implies that τ^k has to be zero in the long run. Overall, the addition of housing and a property tax rate does not change the key finding of the Chamley model.

2.2.2 Heterogeneous agents

Atkeson et al. (1999) show that the basic Chamley result is robust to allowing for households with heterogeneous capital endowments. The important insight is that in a model with heterogeneous agents, there is one Euler equation for each agent and a corresponding intertemporal condition for the planner for each agent. Thus, the planner finds it optimal to set the capital income tax rates to zero. This also has the stark implication that independently of the weight placed on different agents, the optimal capital income tax is zero. Although their result is based on the trade-off between taxing labor versus capital, it is relatively easy to see, given the previous analysis, that the result holds if housing rather than labor is taxed.

2.2.3 Overlapping generations

The result that capital income taxes should be zero in the long run is not confined to models of an infinite horizon. In Appendix 2.A, I show that a similar conclusion can be reached using an OLG model with one young and one old generation alive at each point in time. However, stronger assumptions about the utility functions need to be made compared to the models presented earlier. Specifically, assume that the young generation in period t maximizes its discounted utility

$$U^1(c_{1t}, s_{1t}, n_{1t}) + \beta U^2(c_{2,t+1}, s_{2,t+1}),$$

where c_{1t}, s_{1t} and n_{1t} are non-housing consumption, consumption of housing services, and efficiency hours worked when young (indexed 1), respectively, β is the discount factor, and $c_{2,t+1}$ and $s_{2,t+1}$ are non-housing consumption and consumption of housing services when old (indexed 2).[10] Then, utility functions of the following types are needed to ensure that capital income taxes are zero in steady state

$$U^1(c_{1t}, s_{1t}, n_{1t}) = (c_{1t}^{\alpha} s_{1t}^{1-\alpha})^{1-\sigma}/(1-\sigma) + V(n_{1t})$$

and

$$U^2(c_{2,t+1}, s_{2,t+1}) = (c_{2,t+1}^{\alpha} s_{2,t+1}^{1-\alpha})^{1-\sigma}/(1-\sigma),$$

where α is the expenditure share on non-housing consumption and σ is a parameter of relative risk aversion. As the model I consider is similar to that in Atkeson et al. (1999) — again adapted to include a role for housing services and property taxation — I relegate details on the exact model framework and derivations to Appendix 2.A.

[10] I include a labor choice in the first period because it makes the derivations easier.

2.2.4 Why is a quantitative model required?

Based on the results presented thus far, it appears that the addition of housing and property taxation does not alter the main message of the Chamley result: capital income taxes should be zero in the long run. Why then is there a need for taking the costly step of using a quantitative model? First, results in the previous literature on optimal capital taxation have shown that model features such as borrowing constraints and earnings uncertainty can lead to other conclusions about the optimal capital income tax level (see, e.g., Aiyagari (1995) and İmrohoroğlu (1998)). Incorporating these features generally requires a quantitative framework.

Second, in the models considered so far, housing has simply been another consumption good. Important features of housing have been omitted: households do not only save through deposits but also by increasing their home equity; households decide whether to rent or own; households' ability to borrow is often limited by the amount of housing they own; there are considerable transaction costs of buying and selling houses. The implications of including these model elements for optimal taxation are largely unknown.

Finally, in the context of optimal policy, we are also interested in the short-run welfare effects. The welfare effects of current generations, who have already made decisions based on today's tax system, can potentially differ markedly from those in the long run. Arguably, a quantitative heterogeneous agents model is better suited to capture the distributional consequences of unexpected changes to the tax system.[11]

[11] There is another difference between the theoretical models and my quantitative framework. Specifically, the theoretical models include, either implicitly or explicitly, government debt, whereas there will be no role for government debt in the quantitative model. In this regard, my model assumption is similar to that in Conesa et al. (2009). As noted by these authors, the optimal capital income tax need not be zero in the long run when there is no government debt. It can be

2.3 Quantitative model

To study the optimal level of a property tax on housing, I use a general equilibrium life-cycle model with overlapping generations and incomplete markets. The model is in discrete time, where one model period corresponds to three years. It features four types of agents: households; a representative production firm; a financial intermediary; and a government. For ease of notation, I only write variables with subscripts for individuals i, age j, and time t in cases where they are needed to avoid confusion.

2.3.1 Households

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

Endowments and labor earnings: Households have one unit of time available, which is supplied inelastically to the labor market. During working age, households face uncertain labor productivity, whereas households' time is unproductive during retirement. Specifically, the productivity of household i at age j is given by

$$n_{ij} = \begin{cases} g_j \pi_{ij} & \forall j \leq J_r \\ 0 & \forall j > J_r \end{cases}$$

where g_j is a deterministic age-dependent component common across households, and π_{ij} is a persistent productivity component. Specifically, the logarithm of the persistent component follows an AR(1)

negative as well as positive.

process

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

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

Pre-tax earnings are given by $y_{ijt} = w_t n_{ij}$ during working age, where w_t is the wage level per labor-efficiency unit at time t. Retirement benefits are capped at $w_t \bar{ss}$. Retirement benefits below the cap are given by $w_t \tau^{rr} n_{iJ_r}$, where $\tau^{rr} \in [0, 1]$ is the replacement rate and n_{iJ_r} is the productivity in the last working-age period. Formally, $y_{ijt} = w_t \min(\tau^{rr} n_{iJ_r}, \bar{ss})$ during retirement. A more detailed description of the productivity components and earnings is provided in Section 2.4.1.

Households are born with initial assets a_{i1t} as in Kaplan and Violante (2014). During working age, households receive $a_{ijt} = w_t \gamma_t n_{i,j-1}$ in the form of bequests, where $\gamma_t \in [0, 1]$ and $n_{i,j-1}$ is the labor productivity in the previous period. As labor is unproductive during retirement, retirees receive bequests as a fraction of their benefits, i.e., $a_{ijt} = \gamma_t y_{ijt}$ for $j > J_r$. In equilibrium, aggregate bequests received by households who are alive equal the amount left by households that die.

Preferences: Households derive instantaneous utility from a consumption good c and housing services s. Formally

$$U_j(c, s) = \begin{cases} e_j \frac{\left(c^\alpha s^{1-\alpha}\right)^{1-\sigma}}{1-\sigma} & \text{if } \sigma > 0, \sigma \neq 1 \\ e_j(\alpha \log(c) + (1-\alpha)\log(s)) & \text{if } \sigma = 1, \end{cases} \tag{2.12}$$

where e_j is an age-dependent equivalence scale that captures changes in household size over the life cycle (see, e.g., Kaplan et al. (2019)), σ

is a parameter of relative risk aversion, and α is the expenditure share on consumption.

There is also a warm-glow *bequest motive* similar to that of De Nardi (2004), given by the bequest function

$$U^B(q') = \begin{cases} \upsilon \frac{(q'+\bar{q})^{1-\sigma}}{1-\sigma} & \text{if } \sigma > 0, \sigma \neq 1 \\ \upsilon \log(q' + \bar{q}) & \text{if } \sigma = 1, \end{cases}$$

where υ is the weight assigned to the utility from leaving bequests, q' is households' net worth, and $\bar{q}$ captures the extent to which wealthier households care more about leaving bequests relative to poorer households. For example, higher values of $\bar{q}$ mean that poorer households have less incentive to increase their net worth for the purpose of leaving bequests. The private discount factor is β and the objective of households is to maximize the expected sum of discounted lifetime utility.

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

Houses: Housing services can either be obtained by owning a house or renting from the financial intermediary. Each unit of housing costs $p_{h,t}$ to buy and $p_{r,t}$ to rent. An owned house of size h' produces housing services through a linear technology $s = h'$. These services have to be consumed by the owner of the house, which implies that households cannot be landlords.

Buying and selling owner-occupied housing is subject to transaction costs. The transaction cost of buying is $\varsigma^b p_{h,t} h'$ with $\varsigma^b \in [0, 1]$. Similarly, the cost of selling a house is $\varsigma^s p_{h,t} h$ with $\varsigma^s \in [0, 1]$, where h is the amount of owner-occupied housing a household enters the period with. Housing depreciates at the rate $\delta^h \in [0, 1]$ in each period, and maintenance of $\delta^h p_{h,t} h$ must be paid by homeowners.

Housing is available in discrete sizes.[12] The choice set of rental ser-

[12]It is thus convenient to require homeowners to pay for maintenance, as the

vices is restricted to the ordered set of discrete sizes $S = \{\underline{s}, s_2, s_3, ..., \bar{s}\}$. Owner-occupied housing is limited to a set H, where the smallest house size $\underline{h}$ in H is larger than the smallest available size in S.[13] Above and including that lower bound, both sets are identical.

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

$$m' \leq (1 - \theta) p_h h'. \tag{2.13}$$

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

Taxes: Households are subject to a range of *linear* taxes. Labor income is subject to both an income tax τ^n and a payroll tax τ^{ss} (only paid by working-age households, represented by the dummy variable $\mathbb{I}^w$). Both of these taxes are fixed throughout the analysis. For ease of notation, let $\bar{y} \equiv (1 - \tau^n - \mathbb{I}^w \tau^{ss}) y$ denote after-tax labor income gross of deductions. Mortgage interest payments are deductible from labor income, which implies that the after-tax interest rate is $\bar{r}^m_t \equiv (1 - \tau^n) r^m_t$. The return on deposits is subject to a capital income tax τ^k_t, which gives an after-tax return of $\bar{r}_t \equiv (1 - \tau^k_t) r_t$. Lastly, the value of an owner-occupied house is subject to a property tax τ^h_t that

house size could otherwise effectively end up between the specified discrete values.

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

is proportional to the house value. The capital income tax and the property tax are the only tax rates that will potentially vary across time.

Recursive formulation of the household problem: Households have one deterministic individual state: j for age. They also have non-deterministic individual states, which I will denote $\mathbf{z} \equiv (n, x, h, m)$. Recall that n is total labor productivity, h is the size of owner-occupied housing, and m is the mortgage. Let cash-on-hand be $x = \bar{y} + a$ for $j = 1$ and

$$x = \bar{y} + (1 + \bar{r})d - (1 + \bar{r}^m)m + ((1 - \varsigma^s) - \delta^h - \tau^h)p_h h + a$$

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

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

$$V^k_{j,t}(\mathbf{z}) = \max_{c,s,h',m',d'} U_j(c, s) + \beta \left(\phi_j \mathbb{E}_{j,t} \left[V_{j+1,t+1}(\mathbf{z}') \right] + (1 - \phi_j) U^B(q') \right) \quad (2.14)$$

subject to

$$\begin{aligned}
& c + d' + \mathbb{I}^R p_{r,t} s + \mathbb{I}^B (1 + \varsigma^b) p_{h,t} h' + \mathbb{I}^S (1 - \varsigma^s) p_{h,t} h \leq x + m' \\
& q' = \left(d' + p_{h,t} h' - m' \right) / \left(\alpha + (1 - \alpha) p_{h,t} \right) \\
& h' = s \quad \text{if } h' > 0 \\
& h' = 0 \quad \text{if } k = R \\
& m' \geq 0 \quad \text{if } h' > 0 \\
& m' = 0 \quad \text{if } h' = 0 \text{ and/or } j = J
\end{aligned}$$

and $c > 0, s \in S, h' \in H, d' \geq 0$. The first constraint in the recursive problem is the budget constraint, where the left-hand side of the inequality is total expenditures and the right-hand side of the inequality is the total funds available to spend. For all $k \in \{R, B, S\}$, a household chooses how much to consume c and how much to save in deposits d'. Additional costs occur depending on the specific living situation. In the renter case $\mathbb{I}^R = 1$, the household needs to pay the cost of renting $p_{r,t}s$. In the buyer case $\mathbb{I}^B = 1$, the household needs to pay for the house purchase and incurs transaction costs by doing so. The total cost is thus $(1 + \varsigma^b)p_{h,t}h'$. As cash-on-hand x is defined such that it includes the value of the house when sold, $(1 - \varsigma^s)p_{h,t}h$ is added to the budget constraint as an expenditure in the stayer case, i.e., whenever $\mathbb{I}^S = 1$. Households can cover their costs by spending their cash-on-hand x or by lending $m' > 0$ whenever they buy or stay in an owner-occupied house. Stayers that increase their mortgage and buyers of new homes have to comply with the LTV constraint (2.13).

The second constraint in the recursive problem shows that the net worth q', which goes into the warm-glow utility function, is deflated by a price index $\alpha + (1 - \alpha)p_{h,t}$. This captures the fact that any change in the house price affects the purchasing power of the agent that receives the bequests. The additional constraints are relatively standard. The solution to the household problem is given by

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

with the corresponding set of policy functions

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

2.3.2 Production

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

Formally,

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

where A is aggregate productivity, α_k is the capital share, and $N_t = N \; \forall t$ since labor is supplied inelastically. As usual the interest rate r_t and wages w_t are given by

$$r_t = A\alpha_k \left(\frac{N}{K_t}\right)^{1-\alpha_k} - \delta^k \tag{2.15}$$

$$w_t = A(1-\alpha_k)\left(\frac{K_t}{N}\right)^{\alpha_k}, \tag{2.16}$$

where δ^k is the depreciation of capital.

2.3.3 Financial intermediary

There is a financial intermediary that operates as a bank and the sole provider of rental services. All **Deposits** $(D_{f,t})$ saved by households are invested in the intermediary at the interest rate r_{t+1} and used to finance the intermediary's operations. The subscript f indicates that the variable is specific to the financial intermediary. The intermediary provides mortgages to households, buys and rents out housing stock to households, and lends capital to the production firm. For simplicity, assume that the intermediary only lives for two periods and earns zero profits.

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

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

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

$$p_{r,t} = \frac{1}{1 + r_{t+1}} \left((\delta^h + \eta + \tau^h_{t+1}) p_{h,t+1} + (r_{t+1} + \Delta p_{h,t}) p_{h,t} \right). \quad (2.17)$$

2.3.4 Government

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

PAYG: The payroll tax τ^{ss} is adjusted to make the PAYG system clear

$$\sum_{j=1}^{J} \Pi_j \mathbb{I}^w \int \tau^{ss} n_j(\mathbf{z}_j)\, d\Phi(\mathbf{z}_j) = \sum_{j=1}^{J} \Pi_j (1 - \mathbb{I}^w) \int \min\{\tau^{rr} n_{J_r}(\mathbf{z}_j), \bar{ss}\}\, d\Phi(\mathbf{z}_j), \quad (2.18)$$

where Π_j is the age distribution of households with $\sum_{j=1}^{J} \Pi_j = 1$ and Φ is the cross sectional distribution of the non-deterministic individual states at age j, i.e., $\mathbf{z}_j$. The left-hand side of equation (2.18) is the average payroll tax paid by all households. The right-hand side is equal to the average amount of pension benefits received by all households. The wage level w_t plays no role in finding τ^{ss}, as it is a scaling factor to both sides of the equation.

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

$$\begin{aligned}\mathfrak{q}_{jt}(\mathbf{z}_{j,t-1}) &= (1+r_t)d'_{j,t-1}(\mathbf{z}_{j,t-1}) + (1-\varsigma^s-\delta^h)p_{h,t}h'_{j,t-1}(\mathbf{z}_{j,t-1}) \\ &\quad - (1+r_t^m)m'_{j,t-1}(\mathbf{z}_{j,t-1}).\end{aligned}$$

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

$$\mathfrak{q}_t = \sum_{j=1}^{J} \Pi_j(1-\phi_j) \int \mathfrak{q}_{jt}(\mathbf{z}_{j,t-1})\, d\Phi(\mathbf{z}_{j,t-1}). \tag{2.19}$$

Part of these bequests are distributed to newborns so that a newborn household has initial assets $a_{1t}(\mathbf{z}_{1t})$ similar to those in the data, where the index 1 indicates period $j=1$. The remainder is given to households that are still alive. Recall that bequests received are $a_{jt}(\mathbf{z}_{jt}) = \gamma_t w_t n_{j-1}(\mathbf{z}_{jt})$ for $j \in \{2, ..., J_r\}$ and $a_{jt}(\mathbf{z}_{jt}) = \gamma_t y_{jt}(\mathbf{z}_{jt})$ for $j \in \{J_r+1, ..., J\}$. The parameter γ_t is adjusted such that

$$\mathfrak{q}_t = \sum_{j=1}^{J} \Pi_j \int a_{jt}(\mathbf{z}_{jt})\, d\Phi(\mathbf{z}_{jt}), \tag{2.20}$$

where $\mathfrak{q}_t$ is given by equation (2.19).

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

$$G = \sum_{j=1}^{J} \Pi_j \int \Gamma_{jt}(\mathbf{z}_{jt})\, d\Phi(\mathbf{z}_{jt}) + \tau_t^h p_{h,t} H_{f,t-1}, \tag{2.21}$$

where taxes $\Gamma_{jt}(\mathbf{z}_{jt})$ are

$$\Gamma_{jt}(\mathbf{z}_{jt}) = \tau^n \left(y_{jt}(\mathbf{z}_{jt}) - r_t^m m_{jt}(\mathbf{z}_{jt}) \right) + \tau_t^k r_t d_{jt}(\mathbf{z}_{jt}) + \tau_t^h p_{h,t} h_{jt}(\mathbf{z}_{jt})$$

and property taxes paid by the financial intermediary $\tau_t^h p_{h,t} H_{f,t-1}$ are levied on the rental stock bought by the financial intermediary in period $t-1$. The capital income tax τ_t^k adjusts to ensure that government revenues equal government expenditures.

2.3.5 Aggregate variables and market clearing

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

$$C_t + p_{ht} H_t + G + K_{t+1} + \Omega_t \leq Y_t + (1-\delta^k) K_t + p_{ht}(1-\delta^h) H_{t-1}, \tag{2.22}$$

where C_t is aggregate consumption, H_{t-1} is the total housing stock at the beginning of time t, G is government expenditures, K_t is capital at the start of period t, Y_t is total output, and Ω_t is the sum of the transaction costs related to buying and selling houses as well as the intermediation costs of mortgages and those related to the rental business. Specifically, consumption is given by

$$C_t = \sum_{j=1}^{J} \Pi_j \int c_{jt}(\mathbf{z}_{jt})\, d\Phi(\mathbf{z}_{jt}). \tag{2.23}$$

G is given by equation (2.21), whereas H_t is

$$H_t = \sum_{j=1}^{J} \Pi_j \int s_{jt}(\mathbf{z}_{jt})\, d\Phi(\mathbf{z}_{jt}). \tag{2.24}$$

The transaction costs Ω_t associated with housing transactions, mortgage intermediation, and rental services are

$$\Omega_t = \Omega_t^b + \Omega_t^s + \Omega_t^m + \Omega_t^\eta. \tag{2.25}$$

The sum of the transaction costs related to housing purchases is given by Ω_t^b, and is equal to $\sum_{j=1}^{J} \Pi_j \int \mathbb{I}^B \varsigma^b p_{h,t} h'_{jt}(\mathbf{z}_{jt})\, d\Phi(\mathbf{z}_{jt})$, where again $\mathbb{I}^B$ is an indicator value equal to one for households that choose to buy a house. All houses that are bought end up being sold, either voluntarily or by the government upon death, which means that the transaction costs of selling are

$$\begin{aligned}\Omega_t^s = &\sum_{j=1}^{J} \Pi_j \int \mathbb{I}^{h' \neq h \,\cap\, h>0} \varsigma^s p_{ht} h_{jt}(\mathbf{z}_{jt})\, d\Phi(\mathbf{z}_{jt}) \\ &+ \sum_{j=1}^{J} \Pi_j (1-\phi_j) \int \varsigma^s p_{h,t} h'_{j,t-1}(\mathbf{z}_{j,t-1})\, d\Phi(\mathbf{z}_{j,t-1}).\end{aligned}$$

The first term is the transaction cost of selling for households that are alive, where $\mathbb{I}^{h' \neq h \,\cap\, h>0}$ is an indicator value equal to one if a household decides to sell. The second term is the transaction cost for those who died between time period $t-1$ and t and left owned housing behind. The cost of mortgage intermediation is $\Omega_t^m = \sum_{j=1}^{J} \Pi_j \int \kappa m'_{j,t-1}(\mathbf{z}_{j,t-1})\, d\Phi(\mathbf{z}_{j,t-1})$. The total intermediation cost related to rental services is

$$\Omega_t^\eta = \eta p_{ht} H_{f,t-1},$$

where $H_{f,t-1}$ is the amount of rental housing bought by the financial intermediary in period $t-1$.

Aggregate labor is fixed throughout and is given by

$$N = \sum_{j=1}^{J} \Pi_j \int n_j(\mathbf{z}_{jt})\, d\Phi(\mathbf{z}_{jt}). \tag{2.26}$$

In equilibrium, capital demand from the production firm equals capital supplied by the financial intermediary

$$K_t = K_{f,t} \tag{2.27}$$

$$K_{f,t} = D_{f,t} - (1-p_{r,t})p_{ht}H_{f,t} - M_{f,t}, \tag{2.28}$$

where capital supplied $K_{f,t}$ departs slightly from models without housing as part of households' savings are used to fund the rental services provided to tenants $(1-p_{r,t})p_{ht}H_{f,t}$ and to cater to households' demand for mortgages $M_{f,t}$. The financial intermediary receives rental income immediately after it provides rental services to its tenants, and invests the income by lending to the production firm. Thus, only $(1-p_{r,t})p_{ht}$ per unit of the rental stock is effectively needed to cover rental-service operations. Aggregate deposits, the rental stock, and aggregate mortgages are given as follows

$$D_{f,t} = \sum_{j=1}^{J} \Pi_j \int d'_{jt}(\mathbf{z}_{jt})\, d\Phi(\mathbf{z}_{jt}) \tag{2.29}$$

$$H_{f,t} = H_t - \sum_{j=1}^{J} \Pi_j \int h'_{jt}(\mathbf{z}_{jt})\, d\Phi(\mathbf{z}_{jt}). \tag{2.30}$$

$$M_{f,t} = \sum_{j=1}^{J} \Pi_j \int m'_{jt}(\mathbf{z}_{jt})\, d\Phi(\mathbf{z}_{jt}). \tag{2.31}$$

A formal equilibrium definition is relegated to Appendix 2.C.

2.4 Calibration

2.4.1 Independently calibrated parameters

The model is calibrated to match salient features of the U.S. economy. Table 2.1 shows the full set of parameters that are based on estimates from the literature or computed based on data. Although a model period is three years, I show annualized values of the parameters to ease the interpretation.

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

Endowments and labor earnings: The parameters related to labor productivity are based on the estimated earnings process in Karlman et al. (2020). Earnings and productivity levels map one-for-one as I set $w_t=1$ in the initial steady state. Specifically, I take the deterministic life-cycle profile of productivity g_j to be the deterministic life-cycle *earnings* in their paper. The other parameters need some adjustments before they can be used. Indeed, the income process in Karlman et al. (2020) is assumed to consist of an initial productivity shock, a transitory shock, and a permanent shock, whereas in this paper, I assume that productivity follows an AR(1) with an initial shock and a persistent shock. I set the persistence parameter ρ such that the variance of log productivity is increasing roughly linearly up until retirement. I let σ_ν^2 and σ_ξ^2 adjust such that the variance of log productivity for the age group $47-49$ and the variance of log productivity for the age group $23-25$ are the same for the two

Parameter	Description	Value
Demographics		
J_r	Last working period	14 (ages 62-64)
J	Last possible period alive	20 (ages 80-82)
ϕ_j	Survival probability	Bell and Miller (2005)
Endowments and labor earnings		
g_j	Deterministic labor productivity	Karlman et al. (2020)
ρ	Persistence of prod. shock	0.995
σ_ν^2	Var of persistent prod. shock	0.038
σ_ξ^2	Var of initial prod. shock	0.119
τ^{rr}	Replacement rate retirees	0.5
$\bar{ss}$	Maximum benefit retirement	29.6
a_1	Initial assets	Kaplan and Violante (2014)
Preferences		
e_j	Equivalence scale	See text
σ	Coefficient of relative risk aversion	2
Houses		
p_h	House price	1
ς^b	Transaction cost buying house	0.025
ς^s	Transaction cost selling house	0.07
δ^h	Depreciation, housing	0.023
Mortgages		
θ	Down-payment requirement	0.20
κ	Yearly spread, mortgages	0.01
Taxes		
τ^k	Capital income tax	0.36
τ^h	Property tax	0.01
Production		
r	Interest rate	0.066
δ^k	Depreciation, capital	0.067
α_k	Capital income share	0.265
w	Wage	1
A	Aggregate productivity	1.4

Table 2.1: Independently calibrated parameters, based on data and other studies

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

processes. The age group $47 - 49$ was chosen since this is the period with the highest labor productivity.

Following Díaz and Luengo-Prado (2008), the replacement rate for retirees τ^{rr} is 50 percent. The maximum allowable benefit during retirement $\bar{ss}$ is calculated using data from the Social Security Administration (SSA). The value of 29.6 corresponds to around 61 percent of average earnings for working-age households, which is 48.8 in the model. The retirement benefits scale with w_t as shown in Section 2.3.1, which means that the benefits received by retirees move with the wage level.

The initial asset holdings for households a_1 are calibrated as in Kaplan and Violante (2014). I divide households aged 23-25 in the Survey of Consumer Finances (SCF) into 21 groups based on their earnings.[14] For each of these groups, I calculate the share with asset holdings above 1,000 in 2013 dollars and the median asset holdings conditional on having assets above this limit. The median asset value for each group is scaled by the median earnings among working-age households (23-64) in the SCF data. For model purposes, I rescale these asset values with the median earnings of working-age households in my model. Since the initial assets are scaled by earnings, they will move with changes in the wage level.

Preferences: The equivalence scale e_j is equal to the square root of the predicted values from a regression of family size on a third-order polynomial of age. Predicted values were obtained using data from the Panel Study of Income Dynamics (PSID) for the years 1970-1992. In the benchmark model, I set the coefficient of relative risk aversion σ to 2, a standard value in the literature.

Houses: I set the house price p_h to one in the initial steady state. If the housing stock is perfectly elastic, the house price will remain one for all levels of the property tax. I do allow for changes in the house

[14] I use the survey years 1989 to 2013 for the SCF, where all waves are pooled.

price whenever the housing stock is less flexible. The transaction costs of buying and selling a house are taken from Gruber and Martin (2003), who estimate these costs to around 2.5 and 7 percent of the house value, respectively. Based on data from the Bureau of Economic Analysis (BEA), covering the years 1989-2013, I set the depreciation rate of owned housing to 2.3 percent.

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

Taxes: Following Trabandt and Uhlig (2011), I let the capital income tax τ^k be 0.36. This is broadly in line with what papers in the optimal capital taxation literature have been using. Acikgöz et al. (2018), Davis and Heathcote (2005), Domeij and Heathcote (2004), and İmrohoroğlu (1998) all used a capital income tax rate in the range of $0.36 - 0.4$. The key tax rate in this paper is the property tax τ^h, which is 0.01 in the initial economy. This is based on data from the 2013 American Housing Survey (AHS), which show that the median amount of real estate taxes per $\$1,000$ of housing value is approximately 10 dollars.[15]

Production: The interest rate r is equal to the rental rate of total capital R^T less the depreciation of total capital δ^T. Assuming a Cobb-Douglas production function for the total economy, the rental rate is equal to $(Y^T/K^T)\alpha_k^T$, where Y^T is the gross domestic product (GDP) less investments in defense-related capital, K^T includes all non-defense capital, i.e., both residential and nonresidential capital, and α_k^T is the capital income share for total capital K^T which I assume

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

to be 1/3. Using data from the BEA for the years 1997 – 2013, I find that the rental rate of total capital R^T was 0.117 on average. The depreciation rate δ^T is 0.051 and it is computed as the depreciation of total capital divided by total capital. Overall, the values for the rental and depreciation rates imply an interest rate of 0.066.

To compute δ^k, the depreciation rate for production capital in my model, I divide the depreciation of nonresidential capital by the stock of nonresidential capital. This gives a yearly depreciation rate of 0.067.

The capital income share α_k for the production capital in my model is computed as $(R^N K^N)/Y^N$, where $R^N = r + \delta^k$ is the rental income of nonresidential capital, K^N is nonresidential capital, and Y^N is GDP, Y^T, less consumption of housing services. With the assumption that r is the same for all capital types, the capital income share is easily computed and it is equal to 0.265. Thus, the capital income share for nonresidential capital is slightly lower than that for total capital.

Aggregate productivity A can be computed using the equations for the interest rate (2.15) and the wage (2.16). First, solve (2.15) for K_t/N and substitute into (2.16). Second, impose $w_t = 1$ and solve for A to get

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

Since α_k, r, and δ_k are known, A is also known and equal to 1.4.

2.4.2 Internally calibrated parameters

Table 2.2 shows parameters internally calibrated by simulation, along with a comparison between data and model moments.[16] Unless other-

[16] The computational method to solve the model is similar to the one in Karlman et al. (2020).

wise stated, I use data from the SCF.

Parameter	Description	Value	Target moment	Data	Model
Preferences					
α	Consumption weight in utility	0.82	Median house value-to-earnings	2.32	2.32
υ	Utility shifter of bequest	1.3	Share of net worth held by $j = J$	0.03	0.02
$\bar{q}$	Luxury parameter of bequest	2	Homeownership rate, age 74-82	0.80	0.79
Houses					
η	Intermediation cost, rentals	0.031	Homeownership rate, age < 35	0.43	0.34
$\underline{h}$	Minimum owned house size	39	Homeownership rate	0.68	0.68
Taxes					
τ^n	Labor income tax	0.12	Gov. consumption to GDP (G/Y)	0.17	0.17
Equilibrium objects					
β	Discount factor	0.97	Asset market clearing	See text	
γ	Bequest rate	0.09	Bequest clearing	See text	

Table 2.2: Internally calibrated parameters

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

Preferences: The parameter α determines the weight on consumption and housing services in the utility function. I use this parameter to calibrate the median house value relative to earnings, conditional on owning a house. The strength of the bequest motive υ affects how much net wealth households want to leave behind if they die. Thus, I calibrate it to target the share of net worth held by households in the last period. The other bequest parameter $\bar{q}$ determines the extent to which bequests are luxury goods, and it will affect the fraction of households who would want to remain homeowners as they age. For this reason, I calibrate $\bar{q}$ to target the homeownership rate among those who are between 74 and 82 years old.

Houses: I set the intermediation cost of rental housing η to target the homeownership rate for those aged below 35, as it affects how early in life households become homeowners. For example, a higher value of η increases the cost of rental units relative to owner-occupied housing and will, all else equal, increase the homeownership rate for the young. The minimum owner-occupied house size $\underline{h}$ is calibrated to match the overall homeownership rate.

Taxes: I let the tax rate on labor income τ^n adjust such that G/Y is 0.17, which was the average value of government consumption-to-GDP over the years 1989 – 2013 based on data from the BEA. For GDP, I use the model counterpart which excludes investments in national defense and consumption of housing services.

Equilibrium objects: The discount factor β is an equilibrium object in the initial steady state. Specifically, β affects how much households save and adjusts to ensure that capital supply K_f equals capital demand K, where the latter is fixed in the initial steady state as r is taken from data. In all other steady states, the discount factor is held constant and the interest rate varies. The bequest rate γ is also an equilibrium object and it is the solution to the bequest scheme given by equation (2.20). The value of γ will vary with the different policy experiments.

2.5 Results

2.5.1 Optimal property taxation in the long run

The Chamley-Judd result discussed in Section 2.2 is concerned with optimal capital income taxation in the long run. The analysis of optimal property taxation presented in this section begins with a similar long-run perspective. Specifically, what property tax level maximizes welfare when it can be set without considering its impact on current generations and the transition to the new steady state?

In order to answer this question, I need an interpretable measure of welfare to compare policies. Let τ^h be a specific policy, where τ^h is a proportional tax on the house value. Moreover, let $\tilde{\beta}^j \equiv \beta^j \prod_{k=1}^{j} \phi_k$ be the effective discount factor for streams of utility at age j from the perspective of a newborn. Then, the ex-post value function (welfare) for newborn i under policy τ^h is

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

where $c_{ij}(\tau^h)$, $s_{ij}(\tau^h)$, and $q'_{ij}(\tau^h)$ are the realized values of consumption, housing services, and net worth of household i at age j under policy τ^h.

To evaluate the welfare effects across policies, I use the consumption equivalent variation (henceforth CEV). CEV is the per-period percentage change in consumption needed to make a household indifferent between the initial steady state and the steady state with policy τ^h. Let $\Delta_i(\tau^h)$ denote the household-specific CEV which solves the following equation

$$\sum_{j=1}^{J} \tilde{\beta}^{j-1} \left[U_j \left(\left[1 + \Delta_i(\tau^h) \right] c_{ij}(\tau_0^h), s_{ij}(\tau_0^h) \right) + \beta(1-\phi_j) U^B \left(q'_{ij}(\tau_0^h) \right) \right] = V_i(\tau^h),$$

where $c_{ij}(\tau_0^h)$, $s_{ij}(\tau_0^h)$, and $q'_{ij}(\tau_0^h)$ are the realized values of consumption, housing services, and net worth for household i at age j in the initial steady state with policy τ_0^h. When $\tau^h = \tau_0^h$, there is no change in policy and $\Delta_i(\tau^h) = 0$ for all i. The new policy is welfare improving whenever $\Delta_i(\tau^h)$ is greater than zero. The higher is $\Delta_i(\tau^h)$, the better off is the household.

I assume that the social planner wants to maximize the average ex-post CEV of newborns.[17] Specifically, the planner problem is

$$\max_{\tau^h} \int_0^1 \Delta_i(\tau^h)\,\mathrm{d}i.$$

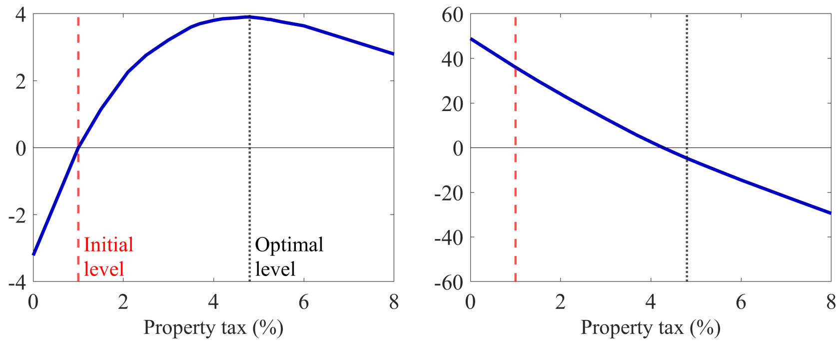
The planner chooses τ^h freely, but must take a series of restrictions into account. First, the government constraint (2.21) needs to hold. As government spending G is assumed to be fixed, I let the capital income tax rate τ^k adjust to ensure that the government's net revenues equal G. I do not allow the government to borrow or lend. Second, the amount of bequests left should equal the amount received by households. The bequest parameter γ adjusts such that bequests balance under all policies. Third, any equilibrium must be a competitive equilibrium, where the interest rate adjusts to ensure that capital demand by the production firm equals capital supply. Finally, in the benchmark model, I assume that the housing supply is perfectly elastic, which implies that the house price is unity across all policies considered. In Section 2.5.3, I show the results of an analysis where the housing supply is less than perfectly elastic.

I find that the optimal property tax for newborns is significantly higher than its current level. Figure 2.1a shows the average CEV for newborns across a range of policies τ^h. The vertical dashed line indicates the initial property tax level of 1 percent. As discussed above, average welfare is zero at this point. Average welfare has a clear hump-shaped pattern and reaches its maximum at a property tax level of 4.8 percent, as indicated by the dotted vertical line. There

[17] Sommer and Sullivan (2018) and Karlman et al. (2020) also compute welfare as the average CEV of households in their analyses. I will later discuss heterogeneous welfare effects across households, and the chosen welfare measure makes the mapping between individual and average effects easier. Note that in steady state, the planner problem is reminiscent to maximizing total welfare, i.e., utilitarian welfare, because of the functional form of the utility function. As a robustness check, I have also computed the optimal property tax rate for a utilitarian planner and find an optimal tax rate of 4.8 percent in that case as well.

are large gains from the considerable increase in the property tax rate. Specifically, moving to the optimal property tax level is equivalent to an average per-period increase in the initial steady-state consumption of 3.9 percent. On the other hand, average welfare is negative for property tax rates below the initial level. A property tax rate of zero would lead to an average CEV close to negative 3 percent.

Figure 2.1b shows the capital income tax rate needed in order to keep government expenditures G constant. Clearly, the higher is the property tax, the more the capital income tax rate can be reduced. At the optimal property tax level, the capital income tax is slightly negative, but close to zero (-4.8 percent).



(a) Average ex-post CEV (%) for newborns

(b) Capital income tax (%)

Figure 2.1: Optimal taxation in the long run

Note: Figure 2.1a shows the average CEV in percent for newborns across different property tax levels. "Initial level" refers to the property tax level currently in place in the U.S., which is one percent. "Optimal level" refers to the property tax rate which maximizes the average CEV for newborns. Figure 2.1b shows the capital income tax rate needed to keep government expenditures G constant across different property tax levels.

The trade-off between keeping down the cost of housing and increasing the production capacity of the economy is evident in Table 2.3, which compares aggregate variables and prices between the initial and the optimal steady state. One the one hand, the higher property tax in the optimal steady state increases the user cost of housing for both owner-occupied housing and rental services. The rental price, for example, is up by 16 percent. In response to the higher cost, housing demand falls and the housing stock is down by almost one fourth. Fewer households find it worthwhile to become homeowners, and the fraction of homeowners drops from more than two thirds to less than one half, a change particularly driven by the response of young households. On the other hand, a lower capital income tax rate increases the demand for savings in deposits which, in turn, drives up capital, output, and wages. With more capital, the pre-tax return falls to 4.2 percent from 6.6 percent. However, there is actually a small increase in the after-tax return to capital as the fall in the capital income tax rate more than outweighs the drop in the pre-tax return. Households benefit from higher earnings by, e.g., an increase in consumption of around 7 percent.

Overall, it is clear that the gain from not distorting the intertemporal savings decision of households is a crucial determinant of the optimal property tax rate. To some extent, this may not be surprising given that the utility function (2.12) is of the form needed to arrive at the zero-tax result in the OLG model specified in Section 2.2.3. Still, it is interesting that the theoretical result survives all bells and whistles added in the quantitative model in Section 2.3. As I will show in Section 2.5.3, the result is sensitive to allowing for a less elastic housing supply function, however.

The aggregate results do not inform us about the extent to which households agree on the optimal property tax level. Therefore, Figure 2.2 shows the optimal property tax rate across initial labor productivity n_{i1}.[18] The optimal property tax rate decreases with the level of initial productivity. Whereas the welfare of households at the bottom 20

[18] Based on their initial productivity, households are divided into quintiles and each marker shows the property tax rate that maximizes the average CEV within a specified quintile.

Variable	Initial steady state	Optimal steady state
Normalized variables		
D: Deposits	1	1.36
K: Capital	1	1.36
Y: Output	1	1.09
C: Consumption	1	1.07
H: Housing stock	1	0.76
w: Wage level	1	1.09
p_h: House price	1	1
p_r: Rental price	1	1.16
Other		
r: Interest rate (%)	6.60	4.16
$\bar{r}$: Interest rate after tax (%)	4.22	4.36
Fraction homeowners	0.68	0.45
Fraction homeowners, below age 35	0.35	0.18

Table 2.3: Change in key aggregate variables: initial versus optimal steady state

Note: In the initial steady state, the property tax is one percent and the capital income tax rate is 36 percent. As shown in Figure 2.1a, the optimal property tax rate is 4.8 percent. The optimal capital income tax rate is −4.8 percent, as seen in Figure 2.1b.

percent of the distribution is maximized when the property tax is 5.3 percent, the top 20 percent are best off when the property tax rate is 3.7 percent. The corresponding capital income tax rates are −8.6 percent and 5.5 percent, respectively. Recall that the model with heterogeneous agents in Section 2.2.2 implied that all households want a capital income tax rate of zero percent.

The departure from the theoretical results in Section 2.2.2 is driven by two distinct mechanisms. First, in the theoretical framework, households could borrow more easily from their future income as they were merely subject to a natural borrowing limit. In the quantitative model, negative deposits are not allowed and poorer households are likely to be constrained. A higher property tax, resulting in a subsidy on capital income, increases the wage level and pushes poorer households away

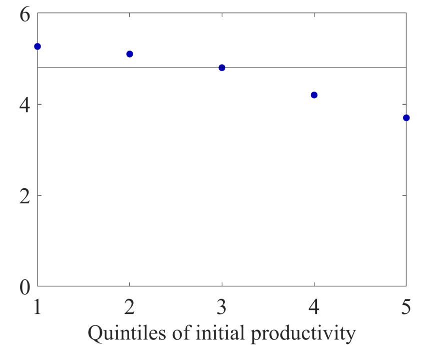


Figure 2.2: Optimal property tax rates (%) across initial productivity
Note: Initial productivity refers to labor productivity n_{i1}, i.e., the productivity of household i at age $j = 1$. Households are divided into quintiles based on their productivity and each marker shows the property tax rate which maximizes the average CEV within a specific quintile. The horizontal line indicates the optimal property tax rate for the economy as a whole, i.e., the property tax rate at which the average CEV for all newborns is maximized.

from the constraint. As a result, low-productivity households generally favor a higher property tax level as compared to other households.

The second mechanism relates to how the tax policies affect the rate of return to owner-occupied housing. In my model, the return to owning a house is the cost of rental housing less the cost of owner-occupied housing. Clearly, the return is positive as most households become homeowners in the initial economy, despite large transaction costs for buying and selling houses.

The cost per housing unit, ignoring discounting, for providing rental services in steady state is

$$C_r = \delta^h + \eta + \tau^h + r.$$

For a homeowner, the flow cost, i.e., the cost excluding transaction costs is

$$C_o = \delta^h + \bar{r} + \tau^h,$$

where the second term $\bar{r} = (1 - \tau^k)r$ captures the opportunity cost of investing in housing rather than deposits. For simplicity, I abstract from the cost of mortgage financing. Thus, the net benefit of owning is

$$\mathcal{N}_o = C_r - C_o = \eta + \tau^k r. \tag{2.32}$$

Equation (2.32) shows that the return to owning a house increases in the intermediation cost of providing rental services, the capital income tax, and the interest rate. Intuitively, the term $\tau^k r$ is the tax savings from not investing in deposits. It shows up because there is no tax on the imputed rent of owner-occupied housing. Notice that the property tax considered in my experiments is not a tax on imputed rent as any change in the property tax affects the rental cost and the flow cost for owner-occupied housing to an equal extent.

Highly productive households benefit less from a lower capital income tax than other households because owned housing becomes a less lucrative savings option. Households in the top quintiles have higher earnings and a larger probability of being born with some initial assets, both of which make it easier for them to enter the housing market. In the initial steady state when τ^k and r are relatively high, a substantial fraction of these households choose to buy a home instead of saving through deposits. Importantly, a higher return of owner-occupied housing relative to deposits is possible due to high transaction costs and the down-payment requirement. When the planner sets a higher property tax rate, the excess return to owner-occupied housing becomes lower as both τ^k and r fall.

The above discussion sheds some light on an additional positive effect of leaving capital income untaxed. A previous branch of the literature has considered a tax on the imputed rent of owner-occupied housing to reduce the preferential tax treatment of housing relative to other types of capital, see, e.g., Gervais (2002) and Floetotto et al. (2016). Another way of avoiding the tax distortion, however, is simply to stop taxing capital income.[19] This also shifts savings from housing to more productive capital. Echoing the results of Gervais (2002), I find that high-productivity households delay their housing purchases and allocate more of their funds to deposits. This additional channel may also help explain why the long-run optimal capital income tax rate is close to zero in my model, despite the inclusion of a life-cycle structure, uncertain earnings, and borrowing constraints.

2.5.2 Optimal property taxation in the short run

Current generations

Thus far, the analysis has been limited to the study of optimal property taxation in the long run. The analysis has fully disregarded any welfare effects of current generations due to changes in the tax system. To capture the consequences for these generations, this section is devoted to studying the optimal property tax rate for households alive at the time of a policy change.

Assume that the social planner chooses a policy τ^h to maximize the average ex-post CEV for households alive today. Formally,

$$\max_{\tau^h} \sum_{g=1}^{J} \Pi_g \int_0^1 \Delta_{ig}(\tau^h)\, \mathrm{d}i,$$

where g is a generation of age g at the time of policy change, Π_g is the age distribution of households, and $\Delta_{ig}(\tau^h)$ is the ex-post CEV for household i in generation g under policy τ^h. Specifically, $\Delta_{ig}(\tau^h)$

[19] In concurrent work, Nakajima (2019) makes a similar claim.

is the percentage per-period change in initial consumption needed to make the household indifferent between the policy τ^h and the initial steady state with policy τ^h_0. As the planner cares about all current generations in the short-run analysis, the welfare computations are somewhat more complicated than in the long run. The interested reader is referred to Appendix 2.B for detailed information on how $\Delta_{ig}(\tau^h)$ is derived.

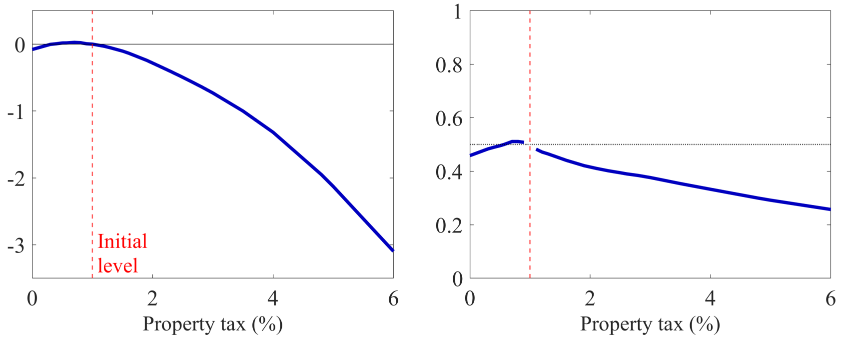
I consider one-time changes in the property tax rate and assume that any policy τ^h is credible and implemented unexpectedly.[20] For each policy, I solve for the transition path of the economy from today's policy τ^h_0 to the steady state with policy τ^h. Along the transition path, there will be a sequence of the capital income tax rate $\{\tau^k_t\}^T_{t=1}$, a sequence of the bequest parameter $\{\gamma_t\}^T_{t=1}$, and a sequence of the interest rate $\{r_t\}^T_{t=1}$, where T is the last period of the transition. Specifically, for each period, the capital income tax rate ensures that the tax revenues exactly cover government expenditures G, the bequest parameter ensures that bequests received equal bequests left behind, and the interest rate clears the capital asset market. Again, I assume that the housing supply is fully elastic. In Section 2.5.3, I show the results when I assume a housing supply which is less elastic.

Figure 2.3a shows the average welfare effect of households alive at the time of a policy change across a range of policies τ^h. The optimal property tax rate is 0.7 percent, which renders a capital income tax rate of around 40 percent. The positive welfare effect is modest, with an average CEV of 0.03 percent. Alternatively, suppose that the planner chooses to increase the property tax rate to 4.8 percent, which is the optimal level in the long run. Such a policy would entail

[20]Note that since the policy change is unexpected, I adjust households' cash-on-hand in the first period of transition in two ways. First, cash-on-hand is adjusted for the new property tax rate and the capital income tax rate τ^k_1. Second, the profits of the rental business are affected by unexpected changes in the property tax rate. Any loss or gain is distributed to households in proportion to their deposit holdings just before the policy announcement.

substantial losses to current generations, equivalent to an average per-period reduction in the initial steady-state consumption of almost two percent. As a comparison, the average and positive CEV of newborns in the long run was almost four percent at the same tax rate.

The fraction in favor of each policy is shown in Figure 2.3b, where a household is in favor if its CEV is greater than or equal to zero. Around 51 percent of households would be in favor of setting the property tax rate to the optimal level of 0.7 percent. In contrast, only thirty percent of households would be in favor of a move to the optimal property tax rate in the long run. Clearly, the optimal property tax rate in the short run is very different from that in the long run.



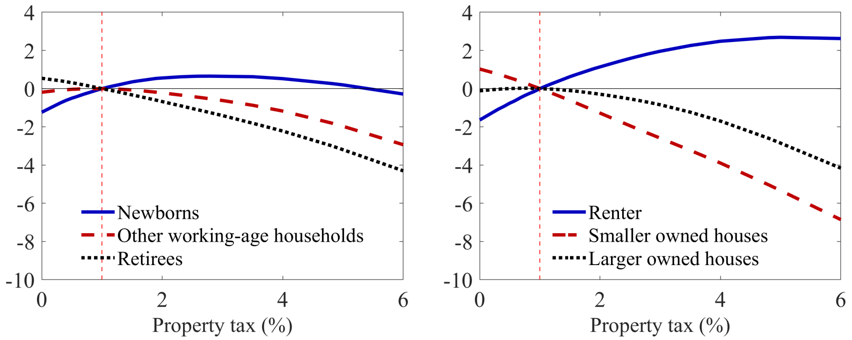
(a) Average ex-post CEV (%) **(b)** Fraction in favor

Figure 2.3: Optimal taxation in the short run: current generations
Note: Figure 2.3a shows the average CEV in percent across property tax reforms, for households alive at the time of a policy change. "Initial level" refers to the property tax level currently in place in the U.S., which is one percent. Figure 2.3b shows the fraction of households that are in favor of a reform across property tax reforms. The fraction in favor is not defined at the initial tax level, which explains the gap in the series. The dotted horizontal line indicates the 50 percent threshold.

One possible explanation for why the optimal property tax is lower in the short run is a well-known result in the literature on optimal taxation. Because capital income is predetermined, and therefore fully inelastic, it should be heavily taxed in the first period of a transition. Still, the above results also show that capital income should not be taxed at 100 percent. Why is that? First, as argued by Eerola and Määttänen (2013), the incentive to tax capital income is reduced when households have access to another savings vehicle, namely, housing. If the tax on capital income becomes too high, too much of households' savings would be devoted to housing in the years following the policy reform. Second, housing is also somewhat inelastic as lumpy transaction costs create some inertia in the aggregate housing stock. Thus, even if the housing supply is allowed to be fully elastic, housing demand is not. Finally, in my model the economy is populated by heterogeneous agents that are differentially affected by changes in tax rates. As I will show next, this has implications for the optimal policy.

The trade-offs faced by the planner can be better understood by dividing households into groups based on their age and housing situation. Figure 2.4a compares the welfare effects of three different age-groups, namely, "Newborns", "Other working-age households", and "Retirees". As in the long-run analysis, newborns are negatively affected by a reduction in the property tax rate and would, on average, prefer a higher property tax. However, as the economy is slow to adjust, newborns do not want a tax level similar to the optimal property tax rate in the long run. It takes time for the capital stock to grow and the wage will only gradually reach its new, higher steady-state level. Since newborns in the first period of a transition do not reap all the benefits of a lower capital income tax rate, there is a downward shift in welfare relative to the long-run analysis. Indeed, many newborns with a high productivity experience negative welfare effects of increasing the property tax rate.

Retirees are worse off on average when the planner increases the property tax rate, and are on average better off with a lower property tax. These households tend to own their homes, are less affected by changes in the wage, have started to eat off their deposit savings, and have fewer periods left to live. They are negatively affected by an increase in the property tax rate and they gain less from lower capital income taxes and higher wages. The last group of households, “Other working-age households”, would on average prefer a decrease in the property tax rate to 0.8 percent.



(a) Average ex-post CEV (%) by age groups

(b) Average ex-post CEV (%) by housing situation

Figure 2.4: Optimal taxation in the short run: decomposition of aggregate welfare results

Note: Figure 2.4a shows the average CEV in percent for households alive today, where households are divided into three age groups. “Newborns” constitutes ages $23-25$, “Other working-age households” covers the ages $26-64$, whereas “Retirees” includes the remainder. Similarly, Figure 2.4b shows the average CEV based on the housing situation of a household prior to the policy change. “Smaller owned houses” refers to households that own $\underline{h}$, whereas “Larger owned houses” refers to households that own houses of a size larger than $\underline{h}$. In both figures, the vertical dashed line refers to the initial property tax level of one percent.

Figure 2.4b shows the welfare effects of renters, owners of small houses, and owners of larger houses. Renters are relatively poor households that benefit from higher wages and lower capital income taxes. Moreover, they can freely adjust how much housing services they consume. The optimal property tax rate for renters is close to the long-run optimal tax rate for newborns. For homeowners, it is more difficult to adjust the housing size due to the large transaction costs of selling and buying. Although transaction costs make the aggregate housing stock more inelastic, which implies that housing is a good tax source from an efficiency perspective, the same transaction costs lock homeowners into house sizes that are no longer optimal in their view. Additionally, a lower capital income tax and interest rate reduce the net benefit of owning as previously discussed. I find that owners of smaller homes on average want a property tax rate of zero, whereas owners of larger homes want a property tax rate of 0.8 percent. In my model, there is a strong positive correlation between housing and deposits of 0.61. This implies that households with larger homes also tend to have larger deposit holdings and thus benefit more from a reduction in capital income taxes.

What if the planner also cares about future generations?

The social planner may also want to assign some weight to future generations. Formally, suppose that the planner problem is

$$\max_{\tau^h} \sum_{g=1}^{J} \Lambda_{gt} \Pi_g \int_0^1 \Delta_{ig}(\tau^h)\, \mathrm{d}i + \sum_{t=2}^{\infty} \Lambda_{1t} \int_0^1 \Delta_{i1t}(\tau^h)\, \mathrm{d}i,$$

where the first term captures the welfare effects of the current generations and the second term comprises the welfare of all future generations of newborns. Here, $\Delta_{i1t}(\tau^h)$ corresponds to the CEV for newborn i at time t under policy τ^h. The parameter Λ_{gt} determines the weight assigned to generation g at time t. Denote the normalized population distribution by $\tilde{\Pi}_g \equiv \Pi_g/\Pi_1$, such that each generation of newborns is normalized to one. Then,

$$\Lambda_{gt} = \frac{\tilde{\Pi}_g \Theta^{t-1}}{\sum_{j=1}^{J} \tilde{\Pi}_j + \sum_{t=2}^{\infty} \Theta^{t-1}},$$

where $\Theta^{t-1} \in [0, 1[$ is the social discount factor. In the denominator there is no Θ in the first term because there is no need to discount the welfare of current generations, and there is no $\tilde{\Pi}$ in the second term because of the normalization.

I find that a social planner who values future generations wants to increase the property tax level to 2.6 percent, when the social discount factor Θ equals households' subjective discount factor β of 0.97 (annualized). The optimal level is markedly below the optimal property tax rate in the long run, however.

I also explore the implications of alternative values for the welfare weight Θ. Overall, I find that the long-run optimal tax system only becomes optimal if the social discount factor is very close to 1. For example, even at a high social discount factor of 0.99 (annualized), the optimal property tax rate is no more than 4 percent. That is almost one percentage point lower than the optimal long-run level. Finally, note that the average effective discount factor for households is considerably lower (0.91) than β, as households are also subject to a death probability. The optimal property tax is around 1.5 percent if Θ equals the average effective private discount factor.

2.5.3 Robustness

The previous results are potentially sensitive to a number of assumptions I have made. In this section, I check the robustness of the results to changing three key ingredients in my analysis: the elasticity of intertemporal substitution; the elasticity of housing supply; and the weighting scheme to compute average welfare. For all these robustness checks, I recalibrate the model to match the same data moments as in the benchmark model. As a last sensitivity analysis, I also consider the extent to which the optimal property tax rate in the short run depends on the initial property tax level.

Higher intertemporal elasticity of substitution

The intertemporal elasticity of substitution (IES) is a measure of how willing households are to move resources across time and may thus affect the cost of taxing or subsidizing capital income. In particular, the higher the IES, the larger are the distortions of a non-zero capital income tax. The important parameter affecting households' IES is the parameter σ, which is two in the benchmark model.

Table 2.4 shows how the benchmark results are affected by changing σ to one, i.e., assuming log utility. In the long run, the optimal property tax rate is then 4.5 percent, which is close to the optimal rate in the benchmark model of 4.8 percent. At the optimal level, the capital income tax rate is somewhat closer to zero, reflecting the larger efficiency costs of distorting savings in productive capital. The welfare gains of increasing the property tax rate are similar to those in the benchmark model. Overall, the long-run results appear robust to changing the IES.

The short-run results of a change in the IES are also relatively similar to those in the benchmark model. The optimal property tax rate in the short run is the initial level of one percent. This is somewhat higher than in the benchmark model, where the optimal rate was 0.7 percent. The welfare gain in the benchmark model was small, however. The higher cost of capital taxation due to the increased IES is thus sufficient to make the initial property tax level optimal.

What if the planner does not care about redistribution?

Due to the concavity of the utility function, the social planner has an incentive to redistribute from rich to poor households. Ex ante it was not obvious that this would be important for an optimal policy — at least not concerning the long-run results. As shown in Section 2.2.2, the capital income tax should be zero independently of the weighting scheme in the heterogeneous agents version of the Chamley model.

Ex post, it is evident that households do disagree about the optimal property tax level, both in the short and long run.

In climate economics, a common approach is to weigh countries' welfare by so-called Negishi weights (after Negishi (1960)). This approach is taken in, e.g., Nordhaus and Yang (1996) who study optimal policies within a regional integrated model of climate and the economy. Specifically, the welfare of each country is multiplied by the inverse of its marginal utility of consumption. This way the marginal benefit of an extra dollar of income is equalized across countries. Without Negishi weights, any optimal climate policy would involve large transfers from rich to poor countries, a policy recommendation often perceived as infeasible.

	Property tax (%)	Capital income tax (%)	Welfare (CEV, %)	Fraction in favor
Long run				
Benchmark	4.8	-4.8	3.9	0.95
Higher IES (log utility)	4.5	-1.6	3.8	0.96
Negishi weights	4.2	0.6	2.9	0.93
Less elastic housing supply	8.3	-31.4	7.6	0.99
Short run				
Benchmark	0.7	0.40	0.03	0.51
Higher IES (log utility)	1	0.36	0	N.A.
Negishi weights	0.8	0.38	0.01	0.43
Less elastic housing supply	1.8	0.26	0.05	0.52

Table 2.4: Sensitivity analyses of optimal property taxation
Note: In the initial steady state, the property tax is one percent and the capital income tax rate is 36 percent. Short-run results refer to what is optimal for current generations.

In the context of optimal property taxation, I apply Negishi weights to solve for the optimal property tax rate without the incentive to redistribute from rich to poor households. As seen in Table 2.4, the optimal property tax in the long run is 4.2 percent and thus it is lower than in the benchmark model. At the optimal level, the capital income tax is very close to zero. Intuitively, with Negishi weights, efficiency plays a bigger role and the cost of a non-zero tax on capital income increases. Furthermore, the results are closely aligned with Figure 2.2, which shows that households with a high initial productivity typically want a lower property tax rate. The short-run results are robust to the alternative weighting scheme. The optimal property tax with Negishi weights is 0.8 percent for current generations, but the average welfare gain of lowering the property tax rate by 0.2 percentage points is almost negligible.

Less elastic housing supply and endogenous house prices

In the benchmark model, I assume that the aggregate housing supply is perfectly elastic. This has the strong implication that the house price p_{ht} is fixed at unity under all policies. Thus, in response to an increase in the property tax rate, the user cost of housing increases without any change in the cost of buying a house. With a less elastic housing supply, house prices will decrease whenever the property tax increases. This can potentially affect the cost of taxing property, both in the short and long run.

To investigate the robustness of my results to changing the elasticity of housing supply, I assume that investment in the housing stock at time t takes the following reduced form

$$I_{H,t} = Lp_{ht}^{\epsilon},$$

where L is a fixed amount of new land made available every period, p_{ht} is the house price in period t, and ϵ is the elasticity of housing investment with respect to the house price. Following Favilukis et al. (2017), L can be interpreted as a flow of government-issued permits. I assume that the government sells these permits at a price such that no profits are made in the production of new housing. The extent to which newly available land is turned into actual housing units is then given by p_{ht}^{ϵ}. The higher the price and the higher the elasticity, the more housing is made available. Similar to Kaplan et al. (2019), I set $\epsilon = 1.5$. The aggregate housing stock evolves according to

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

In the initial steady state, I still assume a house price of one. Since $H_t = H_{t+1} = H$ in steady state, L is equal to $\delta^h H$, i.e., the new land covers the depreciated housing stock. Across policy changes, I keep L fixed at the initial level.

The optimal property tax in the long run is considerably higher when housing is less elastic. Table 2.4 shows that the optimal property tax rate is 8.3 percent in the long run, and that capital income should be subsidized by 31.4 percent. The positive welfare effect is almost twice as high as in the benchmark model. At the optimal level, the house price is about 18 percent lower. Despite the house price fall, the aggregate housing stock is down by more than one fourth and the homeownership rate falls to 39 percent. The housing stock and homeownership rate fall by similar amounts in the optimal steady state with a perfectly elastic housing supply, but then the property tax is substantially lower.

The results for the optimal property tax for current generations are less sensitive. Table 2.4 shows that the optimal property tax increases from the initial level of one percent to 1.8 percent when the housing supply is less elastic.[21] The average welfare effect of the policy is small and equivalent to an average CEV of 0.05 percent and thus similar in magnitude to the welfare gain in the benchmark model. In this robustness check, I effectively add another stock that is perfectly inelastic in the first period of transition, i.e., the stock of housing. A priori it is therefore tempting to believe that the optimal property tax should be much higher compared to the case when housing was

[21] With Negishi weights, the optimal level is 1.7 percent.

fully elastic. However, such an argument does not take into account that the aggregate house value is still flexible as house prices react instantaneously to any policy change. Whenever the property tax increases, homeowners will experience, potentially large, negative wealth effects.

Does the initial property tax matter for the short-run optimal policy?

In this section, I explore whether the initial tax level is important for the short-run results. In particular, suppose that the economy starts off at today's property tax level τ_0^h, but that the government decides to change the property tax rate to some level τ_1^h and that the economy converges to the new steady state. I then take this new steady state as the point of departure and solve for the short-run optimal tax levels.

In Table 2.5, I consider two values for the new property tax level τ_1^h and find that the benchmark result is surprisingly robust to changing the tax level from which short-run policies are evaluated. First, I assume that the economy has converged to a steady state with a property tax of zero percent. As in the benchmark model, the optimal property tax is 0.7 percent for households that are alive at the time of the policy change. Second, assume that the economy has converged to a steady state where the property tax is at the optimal long-run rate, i.e., τ_1^h is 4.8 percent. Then, the optimal tax rate in the short run is 0.9 percent, which is only 0.2 percentage points higher than when the economy starts off at a rate of one percent. Almost three fourths of households would be in favor of reducing the property tax rate, and the average welfare gain of reducing the property tax is large, with an average CEV of about two percent.

Why do households want to move away from the long-run optimal level? Recall that the optimal tax level in the long run was defined as the property tax rate which maximizes the average welfare of newborns.

This is a natural measure for comparing steady states, as the welfare of a newborn takes into account the utility throughout its life. Adding the welfare of other generations would effectively lead to a too high weight on older households. The welfare of older households would be counted both for the old directly and as discounted welfare for younger households; see, e.g., Conesa et al. (2009). In a short-run analysis, however, households at different ages are also different households.

Initial property tax (%)	0	1	4.8
Households alive			
Optimal property tax (%)	0.7	0.7	0.9
Fraction in favor	0.55	0.51	0.70
Average CEV (%)	0.07	0.03	1.96
Social planner's optimal property tax (%)	2.6	2.6	2.3

Table 2.5: Optimal property taxation in the short run: different initial property tax rates

Note: The table shows the results of optimal property taxation in the short run when starting from different initial levels of the property tax rate. The first row indicates the starting value of the property tax. The column with one percent shows the benchmark results. The column with 4.8 percent shows the results of starting from the tax rate that is optimal in the long run.

Households that are alive in the long-run optimal steady state at the time of a policy change prefer a lower property tax and a higher capital income tax for at least two key reasons. First, older generations consume more housing services as compared to younger households and thus benefit substantially from a lower property tax rate. Second, the capital stock is less elastic in the short run, alleviating the costs of taxing capital.

In the last row of Table 2.5, I show the optimal property tax rate in the view of a social planner with welfare weight of $\Theta = \beta$. Independently of the initial property tax rate, the planner wants a property tax close to the benchmark result of 2.6 percent.

To sum up, the optimal property tax rate is relatively robust to the initial property tax rate. In particular, there are strong forces in the short run that drive the property tax rate away from the long-run optimal level and towards today's tax system. A long-run perspective can indeed be very misleading for setting the actual policy.

2.6 Concluding remarks

The purpose of this paper is to enhance our understanding of how we should tax residential property. As a step towards this goal, I let housing play a main role in the otherwise established framework of optimal taxation. The results of my long-run analysis generally support the traditional view held by many economists: property taxes should be substantially increased. I find that, in the long run, the optimal property tax is about five times higher than today's level of one percent. The optimal policy allows the government to set the capital income tax close to zero. Households' welfare improve significantly as a lower capital income tax expands the stock of productive capital. However, in the short run, I show that the optimal policy for current generations is to keep the property tax close to today's level. It is less costly to tax capital in the short run as capital is more inelastic. Moreover, it is costly to tax property in the short run as it will affect many homeowners and retirees negatively.

The core results in this paper are qualitatively, and to a large extent also quantitatively, robust to a range of additional tests. First, I double the intertemporal elasticity of substitution to increase the cost of taxing capital. Second, I allow for endogenous house prices to reduce the cost of taxing residential property. Third, I consider a planner that does not care about redistribution. Finally, I show that the short-run results are surprisingly insensitive to the initial steady-state level of the property tax.

Overall, my findings offer an explanation for the apparent disconnect between the view of many economists and the tax rates currently in place in the U.S. Yet, there are interesting extensions to my study that should be considered in future research. First, it would be useful to see how the property tax relates to taxes on non-housing consumption and labor income. Second, to concentrate on the interactions between housing and other capital, I assume that labor is inelastically supplied by households. A natural way forward would be to relax this assumption and consider the effects of including endogenous labor supply. Finally, in the analysis of short-run effects, I study the consequences of a one-time change in the property tax rate. This departs from the typical Ramsey literature which allows for time-varying optimal policies, and future research should work to close this gap.[22]

[22] In this regard, the parametric approaches in Dyrda and Pedroni (2018) and Itskhoki and Moll (2019) may serve as a useful starting point.

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Appendices

2.A A two-period OLG model

Assume that at each time t, there is one young generation (indexed 1) and one old generation (indexed 2) alive. The young generation wants to maximize its discounted utility over the two periods

$$U^1(c_{1t}, s_{1t}, n_{1t}) + \beta U^2(c_{2,t+1}, s_{2,t+1}), \tag{2.33}$$

where c_{1t}, s_{1t} and n_{1t} are non-housing consumption, consumption of housing services, and efficiency hours worked when young, respectively, β is the discount factor, and $c_{2,t+1}$ and $s_{2,t+1}$ are non-housing consumption and consumption of housing services when old.

The budget constraint for the young is

$$c_{1t} + (1 + \tau^h_{1t})s_{1t} + k_{t+1} + b_{t+1} = w_t n_{1t} \tag{2.34}$$

and for the old it is

$$c_{2,t+1} + (1 + \tau^h_{2,t+1})s_{2,t+1} = (1 + \bar{r}_{t+1})(k_{t+1} + b_{t+1}), \tag{2.35}$$

where τ^h_{1t} is the property tax for young households in period t, $\tau^h_{2,t+1}$ is the property tax for old households in period $t+1$, $\bar{r}_{t+1} = (1 - \tau^k_{t+1})(R_{t+1} - \delta^k)$ is the after-tax return on savings, b_{t+1} is government debt held by the young generation, and the young generation has no initial capital as there is no bequest motive. I allow for type-specific tax rates to simplify the analysis. The household chooses c_{1t}, s_{1t}, n_{1t}, k_{t+1}, b_{t+1}, c_{2t+1}, and s_{2t+1}. The corresponding first-order conditions are

$$U^1_{c1t} = \lambda_{1t} \tag{2.36}$$
$$U^1_{s1t} = \lambda_{1t}(1+\tau^h_{1t}) \tag{2.37}$$
$$U^1_{n1t} = -\lambda_{1t} w_t \tag{2.38}$$
$$\lambda_{1t} = \lambda_{2,t+1}(1+\bar{r}_{t+1}), \tag{2.39}$$
$$\lambda_{1t} = \lambda_{2,t+1}(1+\bar{r}_{t+1}), \tag{2.40}$$
$$\beta U^2_{c2,t+1} = \lambda_{2,t+1} \tag{2.41}$$
$$\beta U^2_{s2,t+1} = \lambda_{2,t+1}(1+\tau^h_{2,t+1}) \tag{2.42}$$

where λ_{1t} is the Lagrange multiplier on the budget constraint for the young, and $\lambda_{2,t+1}$ is the Lagrange multiplier on the budget constraint for the old. Note that these multipliers are not necessarily constant across time. The Euler equation is as follows

$$U^1_{c1t} = \beta U^2_{c2,t+1}(1+\bar{r}_{t+1}). \tag{2.43}$$

The firm problem is

$$\max_{k_t, n_{1t}} F(k_t, n_{1t}) - R_t k_t - w_t n_{1t}. \tag{2.44}$$

The rental rate and the wage level are given by the firm's first-order conditions of capital and labor

$$R_t = F_{kt} \tag{2.45}$$
$$w_t = F_{n1t}. \tag{2.46}$$

The government constraint is

$$g + \bar{r}_t b_t = \tau^h_{1t} s_{1t} + \tau^h_{2t} s_{2t} + \tau^k_t (R_t - \delta^k) k_t + b_{t+1}. \tag{2.47}$$

The resource constraint is given by

$$c_{1t} + c_{2t} + s_{1t} + s_{2t} + k_{t+1} + g = F(k_t, n_{1t}) + (1 - \delta^k)k_t, \tag{2.48}$$

where $k_0 > 0$. The derivation of the implementability constraint (IC) is slightly different in this case. Start by substituting in for the first-order conditions for c_{1t} (2.36), s_{1t} (2.37), and n_{1t} (2.38) in the budget constraint for the young generation (2.34)

$$U^1_{c1t}c_{1t} + U^1_{s1t}s_{1t} + U^1_{n1t}n_{1t} = -\lambda_{1t}(k_{t+1} + b_{t+1}). \tag{2.49}$$

Continue by substituting in for the first-order conditions for $c_{2,t+1}$ (2.41) and $s_{2,t+1}$ (2.42) in the budget constraint for the old (2.35)

$$\begin{aligned} \beta\left(U^2_{c2,t+1}c_{2,t+1} + U^2_{s2,t+1}s_{2,t+1}\right) &= \lambda_{2t+1}(1 + \bar{r}_{t+1})(k_{t+1} + b_{t+1}) \\ \beta\left(U^2_{c2,t+1}c_{2,t+1} + U^2_{s2,t+1}s_{2,t+1}\right) &= \lambda_{1t}(k_{t+1} + b_{t+1}), \end{aligned} \tag{2.50}$$

where I used equation (2.39) to get from the first to the second equation. Setting (2.49) equal to (2.50), I get the implementability constraint

$$U^1_{c1t}c_{1t} + U^1_{s1t}s_{1t} + U^1_{n1t}n_{1t} = -\beta\left(U^2_{c2,t+1}c_{2,t+1} + U^2_{s2,t+1}s_{2,t+1}\right). \tag{2.51}$$

Note that the resource constraint (2.48) and the implementability constraint represented by (2.51) constitute a competitive equilibrium. Denote the social welfare function in period t

$$\begin{aligned} W(c_{1t}, s_{1t}, n_{1t}, c_{2,t+1}, s_{2,t+1}, \mu_t) = {} & U^1(c_{1t}, s_{1t}, n_{1t}) \\ & + \beta U^2(c_{2,t+1}, s_{2,t+1}) \\ & + \mu_t[U^1_{c1t}c_{1t} + U^1_{s1t}s_{1t} + U^1_{n1t}n_{1t} \\ & + \beta(U^2_{c2,t+1}c_{2,t+1} + U^2_{s2,t+1}s_{2,t+1})], \end{aligned} \tag{2.52}$$

where μ_t is the multiplier on the implementability constraint. In this model, the Ramsey planner needs to assign a weight Θ^t with $\Theta < 1$ to agents in generation t. Specifically, the planner wants to maximize

$$\max \frac{U^2(c_{20})}{\Theta} + \sum_{t=0}^{\infty} \Theta^t W(c_{1t}, s_{1t}, n_{1t}, c_{2,t+1}, s_{2,t+1}, \mu_t), \tag{2.53}$$

where the utility of the current old is given by $U^2(c_{20})$. The planner maximizes (2.53) subject to the resource constraint (2.48). The optimality conditions are

$$\Theta^t W_{c1t} = \Theta^t \chi_t \tag{2.54}$$

$$\Theta^t W_{s1t} = \Theta^t \chi_t \tag{2.55}$$

$$\Theta^t W_{n1t} = -\Theta^t \chi_t F_{n1t} \tag{2.56}$$

$$\Theta^t W_{c2t} = \Theta^{t+1} \chi_{t+1} \tag{2.57}$$

$$\Theta^t W_{s2t} = \Theta^{t+1} \chi_{t+1} \tag{2.58}$$

$$\Theta^t \chi_t = \Theta^{t+1} \chi_{t+1} \left(F_{k,t+1} + 1 - \delta^k \right), \tag{2.59}$$

where $\Theta^t \chi_t$ is the multiplier on the resource constraint in period t. Rearrange the optimality conditions to get

$$W_{c1t} = \Theta W_{c1,t+1} \left(F_{k,t+1} + 1 - \delta^k \right). \tag{2.60}$$

Assume that the economy converges to a steady state such that $(c_{1t}, s_{1t}, n_{1t}, c_{2t}, s_{2t}, k_{t+1}) = (c_1, s_1, n_1, c_2, s_2, k)$ for all t. Then I can rewrite (2.60) as

$$\Theta^{-1} = F_k + 1 - \delta^k. \tag{2.61}$$

From the Euler equation (2.43), I have

$$\frac{U^1_{c1}}{\beta U^2_{c2}} = 1 + (1 - \tau^k)(F_k - \delta^k). \tag{2.62}$$

Comparing (2.61) and (2.62) we see that the capital income tax *in steady state* for this economy is zero only if

$$\Theta^{-1} = \frac{U^1_{c1}}{\beta U^2_{c2}}. \tag{2.63}$$

The next step is to figure out what Θ is in steady state. Use the first-order condition for c_{1t} (2.54) and $c_{2,t+1}$ (2.57) to arrive at the following expression in steady state

$$\begin{aligned}\Theta &= \frac{W_{c2}}{W_{c1}} \\ &= \frac{\frac{W_{c2}}{U^2_{c2}} U^2_{c2}}{\frac{W_{c1}}{U^1_{c1}} U^1_{c1}}.\end{aligned} \tag{2.64}$$

It is relatively easy to see that if $\frac{W_{c2}}{U^2_{c2}} / \frac{W_{c1}}{U^1_{c1}} = \beta$, then the capital income tax is zero in steady state. I now show that this holds for the following utility functions

$$U^1(c_1, s_1, n_1) = (c_1^{\alpha} s_1^{1-\alpha})^{1-\sigma}/(1-\sigma) + V(n_1) \tag{2.65}$$

$$U^2(c_2, s_2) = (c_2^{\alpha} s_2^{1-\alpha})^{1-\sigma}/(1-\sigma). \tag{2.66}$$

Derive W_{c1}/U^1_{c1}

$$\begin{aligned}W_{c1} &= U^1_{c1} + \mu_t \left[U^1_{cc1} c_1 + U^1_{c1} + U^1_{sc1} s_1 + U^1_{nc1} n_1\right] \\ \frac{W_{c1}}{U^1_{c1}} &= 1 + \mu_t \left[1 - \sigma\right].\end{aligned} \tag{2.67}$$

Derive W_{c2}/U^2_{c2}

$$\begin{aligned}W_{c2} &= \beta \left(U^2_{c2} + \mu_t \left[U^2_{cc2} c_2 + U^2_{c2} + U^2_{sc2} s_2\right]\right) \\ \frac{W_{c2}}{U^2_{c2}} &= \beta \left(1 + \mu_t \left[1 - \sigma\right]\right).\end{aligned} \tag{2.68}$$

Together (2.64), (2.67), and (2.68) imply $\Theta^{-1} = U^1_{c1}/(\beta U^2_{c2})$. Thus, in steady state, the capital income tax is zero.

2.B Welfare measure for current generations

Let total utility, including the warm-glow bequest motive, at time t for household i of age j be

$$W_{ijt}(\tau^h) \equiv U_j\left(c_{ijt}(\tau^h), s_{ijt}(\tau^h)\right) + \beta(1-\phi_j)U^B\left(q'_{ijt}(\tau^h)\right),$$

where c_{ijt}, s_{ijt}, and q'_{ijt} are realized values of consumption, housing services and net worth, and τ^h is a policy which is assumed to be credible and fixed over time.

Let generation g be households of age g at the time of the policy change. Then, the value function for household i of generation g under a specific policy τ^h is

$$V_{ig}(\tau^h) \equiv \sum_{j=g}^{J} \tilde{\beta}^j W_{ijt}(\tau^h),$$

where $t = j - g + 1$ is the time period for the utility flow, and $\tilde{\beta}^j = \beta^{j-g}(1/\phi_g)\prod_{k=g}^{j}\phi_k$ is the effective discount factor for streams of utility at age j for a household of generation g. For example, when $g = j$, we are in the first period of the transition so there should be no discounting of utility, i.e., $\beta^0 = 1$ and $(1/\phi_g)\prod_{k=g}^{j}\phi_k = (\phi_g/\phi_g) = 1$.

I denote the ex-post CEV for household i of generation g under policy τ^h as $\Delta_{ig}(\tau^h)$, which is the percentage per-period change in initial consumption needed to make the household indifferent between the policy τ^h and the initial steady state with policy τ^h_0. Formally,

$$\sum_{j=g}^{J} \tilde{\beta}^j \left[U_j\left([1+\Delta_{ig}(\tau^h)]c_{ijt}(\tau^h_0), s_{ijt}(\tau^h_0)\right) + \beta(1-\phi_j)U^B\left(q'_{ijt}(\tau^h_0)\right)\right] = V_{ig}(\tau^h),$$

where $t = j - g + 1$. Whenever there is no policy change, i.e. $\tau^h = \tau_0^h$, then $\Delta_{ig}(\tau^h)$ is zero for all households.

2.C Equilibrium definitions

Households are heterogeneous with respect to age $j \in \mathcal{J} \equiv \{1, 2, ..., J\}$, labor productivity $n \in \mathcal{N} \equiv \mathbb{R}_{++}$, cash-on-hand $x \in \mathcal{X} \equiv \mathbb{R}_{++}$, owner-occupied housing $h \in \mathcal{H} \equiv \{0, \underline{\text{h}}, ..., \bar{h} = \bar{s}\}$, and mortgage $m \in \mathcal{M} \equiv \mathbb{R}_{+}$. Let $\mathcal{Z} \equiv \mathcal{N} \times \mathcal{X} \times \mathcal{H} \times \mathcal{M}$ be the non-deterministic state space with $\mathbf{z} \equiv (n, x, h, m)$ denoting the vector of individual states. Let $\mathbf{B}(\mathbb{R}_{++})$ and $\mathbf{B}(\mathbb{R}_{+})$ be the Borel σ-algebras on $\mathbb{R}_{++}$ and $\mathbb{R}_{+}$ respectively, and $P(\mathcal{H})$ the power set of $\mathcal{H}$, and define $\mathscr{B}(\mathcal{Z}) \equiv \mathbf{B}(\mathbb{R}_{++}) \times \mathbf{B}(\mathbb{R}_{++}) \times P(\mathcal{H}) \times \mathbf{B}(\mathbb{R}_{+})$. Further, let $\mathbb{M}$ be the set of all finite measures over the measurable space $(\mathcal{Z}, \mathscr{B}(\mathcal{Z}))$. Then $\Phi_{jt} \in \mathbb{M}$ is a probability measure defined on subsets $Z \in \mathscr{B}(\mathcal{Z})$ that describes the distribution of individual states across agents with age $j \in \mathcal{J}$ at time t. Finally, denote the time-invariant fraction of the population of age $j \in \mathcal{J}$ by Π_j.

Definition 1. Given a sequence of property tax rates $\{\tau_t^h\}_{t=1}^{t=\infty}$, government expenditures G, and initial conditions Φ_{j1} for all j, a recursive competitive equilibrium with perfectly elastic housing supply is a sequence of value functions $\{V_{jt}(\mathbf{z})\}_{t=1}^{t=\infty}$ with associated policy functions $\{c_{jt}(\mathbf{z}), s_{jt}(\mathbf{z}), h'_{jt}(\mathbf{z}), m'_{jt}(\mathbf{z}), d'_{jt}(\mathbf{z})\}_{t=1}^{t=\infty}$ for all j; a sequence of prices $\{(p_h, p_{r,t}, r_t, w_t)\}_{t=1}^{t=\infty}$; a social security tax τ^{ss}; a sequence of bequest parameters $\{\gamma_t\}_{t=1}^{t=\infty}$; a sequence of capital income taxes $\{\tau_t^k\}_{t=1}^{t=\infty}$; a sequence of production plans for the production firm $\{N, K_t,\}_{t=1}^{t=\infty}$; a sequence of rental stocks $\{H_{f,t}\}_{t=1}^{t=\infty}$; and a sequence of distributions of agents' states $\{\Phi_{jt}\}_{t=1}^{t=\infty}$ for all j such that:

1. Given prices $(p_h, p_{r,t}, w_t, r_t)$ and parameters $(t_t^k, \tau^{ss}, \gamma_t)$, $V_{jt}(\mathbf{z})$ solves the Bellman equation (2.14) with the corresponding set of policy functions for all j and t:

$\{c_{jt}(\mathbf{z}), s_{jt}(\mathbf{z}), h'_{jt}(\mathbf{z}), m'_{jt}(\mathbf{z}), d'_{jt}(\mathbf{z})\}$.

2. The relative price of housing is one, i.e., $p_h = 1$.
3. The interest rate r_t and the wage level w_t satisfy (2.15) and (2.16), respectively.
4. The rental price $p_{r,t}$ satisfies the financial intermediary's optimality condition (2.17).
5. The payroll tax τ^{ss} satisfies (2.18).
6. The bequest parameter γ_t balances bequests left and bequests received (2.20).
7. The capital income tax τ_t^k balances the government budget (2.21).
8. The aggregate resource constraint (2.22) holds, where
   - aggregate consumption C_t is given by (2.23);
   - aggregate housing H_t is given by (2.24);
   - aggregate transaction costs Ω_t are given by (2.25);
   - aggregate labor supply N satisfies (2.26);
   - and aggregate capital K_t is given by (2.27).
9. The capital market satisfies (2.28).
10. The rental stock $H_{f,t}$ satisfies (2.30).
11. Distributions of states Φ_{jt} are given by the following law of motion for all $j < J$ and t:

$$\Phi_{j+1,t+1}(\mathcal{Z}) = \int_{Z_t} T_{jt}(\mathbf{z}, \mathcal{Z}) d\Phi_{jt}(Z_t),$$

where $T_{jt} : \mathcal{Z} \times \mathscr{B}(\mathcal{Z}) \rightarrow [0,1]$ is a transition function that defines the probability that a household of age j at time t transits from its current state $\mathbf{z}$ to the set $\mathcal{Z}$ at age $j+1$ and time $t+1$.

Definition 2. A stationary equilibrium is a competitive equilibrium in which all tax policies, value functions, policy functions, prices and other market-clearing parameters, as well as aggregate quantities, are constant.

Chapter 3

Mortgage lending standards: implications for consumption dynamics*

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3.1 Introduction

Since the Great Recession, there has been an increased concern that high household debt makes the economy more vulnerable to adverse events. This concern partly stems from findings in the literature on the causes of the recession.[1] A prominent result in this line of work is that the rise in household debt in the early 2000's led to a stronger consumption response among households when the crisis hit. Policymakers in many countries have reacted to these findings by introducing stricter lending regulations, with the ambition to reduce the sensitivity of consumption to future shocks. As mortgages are the most common type of debt contract held by households, they have received special attention.[2]

It is not obvious, however, that stricter mortgage regulations dampen the consumption responses. First, by constraining how much households can borrow, households may find it *more* difficult to smooth consumption as their access to credit is reduced. Second, a household that chooses to take up less debt due to new regulations may also respond by lowering its buffer of liquid savings. Thus, households may adjust their asset holdings such that they are no better prepared to handle unexpected shocks.

In this paper, we study whether stricter mortgage lending standards affect consumption responses to shocks. Specifically, we investigate to what extent a permanent or temporary tightening of loan-to-value (LTV) and payment-to-income (PTI) requirements influences households' marginal propensity to consume (MPC) out of a wealth shock.

We have two main findings. First, we show that permanent policies do not materially affect aggregate consumption dynamics. In fact, a

[1]There is a rich literature that studies the causes of the Great Recession and the role of relaxed lending standards, through, for example, securitization of mortgage debt, and increased household debt. See, for example, Mian and Sufi (2014).

[2]For example, Sweden has implemented stricter guidelines on loan-to-income.

permanent tightening of the LTV or PTI constraint only marginally affects the distribution of MPCs across households. Second, a temporary one-period policy, implemented in a year prior to a negative wealth shock, can successfully reduce the consumption fall during the bust. However, such policies are, on average, only beneficial to households under very particular circumstances. The negative wealth shock needs to be large, and the policymaker must have an informational advantage in that she can perfectly foresee the bust, whereas households cannot.

To explore the role of mortgage lending standards for consumption dynamics, we use a heterogeneous-household model that includes housing and long-term mortgages. Since housing tenure and mortgage choices are strongly linked to age, we explicitly model the life cycle. Further, markets are incomplete in the sense that there is idiosyncratic earnings risk that is not fully insurable. Households derive utility from non-durable consumption goods and housings services, where housing services can be obtained by either renting or owning a house. A household can save in liquid, risk-free bonds, but also in housing. Importantly, housing equity is illiquid. First, there are transaction costs associated with both buying and selling a house. Second, there are LTV and PTI constraints that limit the size of new mortgages. Finally, it is costly to use cash-out refinancing to access housing equity.

The model produces a rich distribution of marginal propensities to consume across households.[3] Portfolio choices, both in terms of leverage and liquid bond holdings, play an important role in determining households' MPC. A significant portion of renters hold no or very little liquid bonds and are so-called *poor hand-to-mouth* households with high MPCs. Moreover, a substantial fraction of homeowners

[3]We compute MPC as the change in non-durable consumption in response to an unexpected shock to wealth (cash-on-hand), relative to the size of the shock. The use of the word *marginal* is clearly abused, since we consider shock sizes of varying magnitudes, some of which are quite large. Further, to focus on the direct effects on demand, we abstract from possible propagation mechanisms through changes in, e.g., prices caused by the wealth shocks.

have most of their wealth in illiquid housing, as the return on housing is higher than for risk-free bonds. These households resemble the *wealthy hand-to-mouth*, as described in Kaplan and Violante (2014). However, not every homeowner with low bond savings behaves as a hand-to-mouth consumer. Some homeowners expect to pay off more on their mortgage than what is stipulated by their amortization plan, and can thus choose to costlessly pay off less in response to an adverse shock. As a result, they endogenously choose to hold small amounts of liquid bonds, but are not liquidity constrained. Lastly, households who change their discrete choice, e.g., become renters instead of buying a home in response to a negative wealth shock, tend to have large and negative MPCs.

To quantify the effects of introducing permanently stricter lending standards, we study two considerable changes in the LTV and PTI requirements. In the LTV experiment, homeowners can only borrow up to 70 percent of the value of their home instead of the baseline limit of 90 percent. In the PTI experiment, we lower the maximum ratio of housing-related expenses to earnings that is allowed when taking up a new mortgage, from 0.28 to 0.18.[4] Both policies cause significant changes in the economy. For example, with the stricter LTV requirement, the homeownership rate falls by seven percentage points and the median LTV among homeowners is more than halved.

Despite the considerable changes in policies, we find very small changes in both the aggregate consumption response and the distribution of MPCs across households. This holds for negative wealth shocks of various magnitudes, as well as for larger changes in the lending standards. The main reason for the small differences in MPCs is that households' precautionary savings in the long run are primarily driven by the income risk to which households are exposed and by deep parameters, e.g., households' risk aversion.

[4]For each of these experiments, we solve for a new steady state and the house price changes endogenously to clear the housing market.

In a second round of experiments, we study the effects of LTV and PTI requirements that are temporarily tightened for one period. In these experiments, the negative wealth shock materializes in the period when the constraint returns to its baseline value. A temporary policy of this kind causes some households to save more than they otherwise would, which makes them react less strongly to the bust.

Although temporary policies do affect consumption responses to wealth shocks, there is a trade-off in terms of welfare. On the one hand, households can potentially benefit as the increased savings may make them better equipped to handle a negative wealth shock. On the other hand, temporary policies restrict consumption in the year prior to the bust, and households may already save sufficiently for precautionary reasons. Thus, the temporary policies produce both winners and losers. The winners are mainly households who abstain from buying, and thereby avoid being liquidity constrained during the bust. The losers are typically households with low earnings realizations in the year prior to the bust. These households want to extract housing equity through cash-out refinancing, but the possibility to do so is limited by the policies. Overall, we find that a temporary tightening of mortgage lending standards is only welfare improving on average under certain conditions. First, the negative wealth shock must be very large. Second, a policymaker needs to have an informational advantage in terms of predicting the bust.

This paper is related to the growing strand of literature highlighting how differences in liquidity across asset classes play an important role for a broad range of macroeconomic questions. In their seminal contribution, Kaplan and Violante (2014) show that the inclusion of an illiquid asset is key for producing the high MPCs among wealthy households that are observed in data. We focus our attention on one specific type of illiquid asset, housing, and construct a model with detailed housing and mortgage markets to consider changes in mortgage lending standards. Boar et al. (2020) provide a thorough analysis of the constraints in the U.S. housing market. They show that mortgage forbearance policies, which provide relief to households with a temporary low income, can be welfare improving. Consistent with their findings, we show that households in need of refinancing, i.e., those with a low transitory income, are significantly hurt by temporary stricter LTV and PTI requirements. Greenwald (2018) finds that PTI requirements are more effective than LTV limits in counteracting cyclicality, and highlights their role in the Great Recession. Our model includes a richer heterogeneity among households, which allows us to explore differences in consumption responses across households. Moreover, we consider both permanent and temporary stricter LTV and PTI limits.

On the empirical side, Lim et al. (2011) perform cross-country regressions and find that stricter LTV and debt-to-income limits are linked to a lower cyclicality of debt. Aastveit et al. (2020) show that stricter LTV limits in Norway are associated with lower debt levels, but also a fall in liquid savings, thereby having an uncertain effect on financial vulnerability. This result is much in line with our findings.

There are also a number of papers that consider macroprudential policies and their interactions with monetary policy, of which Angelini et al. (2012) provide a review. Ferrero et al. (2018) focus on the interaction between LTV requirements and monetary policy, and find that the optimal LTV limits are countercyclical. Using a model with richer heterogeneity on the household side and a more detailed mortgage market, we confirm their findings that countercyclical policies can dampen consumption fluctuations. We further emphasize that this result requires strong assumptions on the information availability of policymakers.

The remainder of the paper is organized as follows. In Section 3.2 we describe the model, followed by a calibration and comparison to the data in Section 3.3. Section 3.4 presents the results, and Section 3.5 concludes the paper.

3.2 Model

To study how changes in mortgage lending standards affect the consumption responses of households to shocks, we build a life-cycle model with heterogeneous households and incomplete markets. Households differ in terms of their age, earnings, wealth, housing tenure status, housing wealth, and mortgage debt. Importantly, housing wealth is illiquid due to transaction costs in the housing market as well as debt constraints in the mortgage market. Specifically, households face loan-to-value (LTV) and payment-to-income (PTI) constraints when taking up a new mortgage. To further capture the constraints in the U.S. housing market, mortgages are long-term and subject to amortization plans. To smooth consumption, households may use cash-out refinancing to access their housing equity, but this comes at a cost.

The assets in the model are houses and risk-free liquid bonds. The only source of debt is mortgages. The supply of both mortgages and bonds is fully elastic, and the returns are exogenous. The aggregate housing supply, on the other hand, is inelastic and consists of both owned and rental housing units that are available in discrete sizes. In steady state, the house and rental prices adjust to clear the housing market. In addition to households, there are rental firms that provide rental housing services, and there is a government that taxes the agents and provides social security. Time is discrete, and a model period corresponds to one year. Overall, the model shares many features with the model in Karlman et al. (2020).

3.2.1 Households

The model is a life-cycle model with overlapping generations. There is a unit measure of households i of each age j. When households enter the economy at age $j = 1$, they are provided with different levels of initial net worth. The distribution of net worth among the entering cohort is matched to data, as in Kaplan and Violante (2014). Throughout their lives, households are subject to idiosyncratic earnings risk, consisting of permanent and transitory shocks. There are also age-dependent and households-specific fixed components of earnings. At age J_{ret}, households retire, and from then on they receive social security benefits that are only a share of their permanent earnings in the period before retirement, subject to a cap. In retirement, there is no permanent earnings uncertainty, but households still face transitory income shocks to proxy for expenditure shocks that older people often experience. Households in retirement face an age-dependent probability of surviving to the next period $\phi_j \in [0, 1]$, where $\phi_J = 0$.

In each period, households choose how much to consume of non-durable consumption c and housing services s. Non-durable consumption is the numeraire good in the model. Housing services can be obtained either by renting at a unit price p_r, or by owning a house at a unit price p_h. There is a linear technology that transforms owned housing units h' to housing services s, such that $s = h'$ if $h' > 0$.[5] Thus, homeowners themselves enjoy the full housing services provided by their house and are not allowed to rent out part of their property.

Households have two ways of saving. One is to buy risk-free bonds b', the other is to invest in housing. While the housing supply is fixed in the aggregate, it is flexible in its composition of rental housing and owned housing. There is a set of discrete house sizes available for rent $S = \{\underline{s}, s_2, s_3, ..., \bar{s}\}$. The sizes available for ownership constitute a proper subset H of those available for rent. Specifically, the smallest housing size available for purchase is larger than the smallest size available for rent.[6] There are transaction costs associated with both

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

[6] It is common in the literature to restrict homeownership and create a selection of wealthier households among homeowners by limiting the smallest size available for purchase; see for example Cho and Francis (2011), Floetotto et al. (2016), Gervais (2002), and Sommer and Sullivan (2018).

buying and selling a house. These costs are proportional to the house value, and are given by the parameters ς^b and ς^s, respectively.

If a household chooses to purchase a house, it can take up a long-term, non-defaultable mortgage m'. The interest rate on mortgages r^m is strictly larger than the interest rate r on bonds. A mortgage has an age-dependent repayment plan that specifies the minimum payment to be made in each period. Specifically, χ_j is the share of a mortgage that needs to be paid by a household of age j, where

$$\chi_j = \left(\sum_{k=1}^{M_j} \left[\frac{1}{(1+r_m)^k} \right] \right)^{-1}. \tag{3.1}$$

M_j denotes the maturity of the mortgage. To imitate the most commonly used mortgage contract in the U.S., the 30-year fixed-payment mortgage, the maturity is set to $M_j = \min\{30, J - j\}$. This specification stipulates that the repayment period cannot extend beyond the age of certain death, thus capturing the fact that older people tend not to take up long-term mortgages. A household that wishes to deviate from the minimum-payment schedule provided in equation (3.1) can use cash-out refinancing by paying a fixed cost ς^r.

The use of mortgage financing is further limited by LTV and PTI constraints. Whenever a household takes up a new mortgage, either when buying a new home or when using cash-out refinancing, these constraints need to be fulfilled. The LTV requirement states the maximum allowable mortgage as a fraction $1 - \theta$ of the house value,

$$m' \leq (1 - \theta) p_h h'. \tag{3.2}$$

The payment-to-income (PTI) constraint, on the other hand, restricts the use of a mortgage by specifying that housing-related payments, including mortgage payments, cannot exceed a share ψ of current permanent earnings z,

$$\chi_{j+1}m' + (\tau^h + \varsigma^I)p_h h' \leq \psi z. \tag{3.3}$$

The housing-related payments also include property taxes τ^h, and home insurance payments ς^I, both proportional to the house value.[7]

Households have CRRA preferences over a Cobb-Douglas aggregator of non-durable consumption and housing services.

$$U_j(c,s) = e_j \frac{\left(c^\alpha s^{1-\alpha}\right)^{1-\sigma}}{1-\sigma}, \tag{3.4}$$

where e_j is an age-dependent utility shifter that captures the tendency of household size to vary with the life cycle (see, e.g., Kaplan et al. (2020)). Further, we include a warm-glow bequest motive for households in retirement. The utility from bequests is given by

$$U^B(q') = \upsilon \frac{(q')^{1-\sigma}}{1-\sigma} \quad \text{for } j \in [J_{ret}, J], \tag{3.5}$$

where υ controls the strength of the bequest motive, and bequests q' are given by the net worth of a household, deflated by a price index $\alpha + (1-\alpha)p_h$,

$$q' = \frac{b' + p_h h' - m'}{\alpha + (1-\alpha)p_h}. \tag{3.6}$$

By deflating, a household takes into account the purchasing power of the bequests.

There are five state variables in the household problem: age j, permanent earnings z, mortgage m, house size h, and cash-on-hand x. The state variable cash-on-hand x is defined as

[7] The home insurance payment is only included in the PTI requirement for calibration purposes, as it is an important cost for most homeowners, but it does not enter the budget constraint of the household.

$$x \equiv \begin{cases} (1+r)b - (1+r^m)m + y - \Gamma - \delta^h h + (1-\varsigma^s)p_h h & \text{if } j > 1 \\ y - \Gamma + a & \text{if } j = 1, \end{cases} \tag{3.7}$$

where y is current period earnings or social security benefits, depending on the age of the household; Γ captures all taxes paid by a household; $\delta^h h$ is a maintenance cost that a homeowner has to pay, which is modeled as proportional to the house size; $(1-\varsigma^s)p_h h$ is the value of a house net of the transaction cost for selling the house; and finally, a represents the initial assets of the newborn cohort.

The households face three different taxes. The total tax payment Γ of a household includes social security taxes, property taxes on owned housing, and labor income taxes.

$$\Gamma \equiv \mathbb{I}^w \tau^{ss} y + \tau^h p_h h + T(\tilde{y}), \tag{3.8}$$

where the social security tax is paid only by the working age population, as indicated by the dummy variable $\mathbb{I}^w$. The labor income tax is modeled by the progressive tax and transfer function $T(\tilde{y})$, which takes taxable labor income after deductions $\tilde{y}$ as its argument. For a richer description of the tax system, see Section 3.2.3.

To solve the household problem, we compute the value function in each period separately for four mutually-exclusive discrete cases related to the housing tenure choice of the household. A household can choose to rent a house (R), buy a home (B), stay in an owned house that it enters the period with and follow the repayment plan of any outstanding mortgage (S), or stay in an owned house and take up a new mortgage by refinancing (RF). In each period, the household chooses the tenure status that yields the highest value. The renter case is characterized by a household choosing not to own a house, and it is therefore not allowed to take up a mortgage, i.e., $h' = m' = 0$. In the buyer case, the household buys a new house of a different size than the previous one, i.e., $h' > 0$ and $h' \neq h$. In the stayer and refinancing cases, a household chooses to stay in the owned house it enters the period with, i.e., $h' = h$.

For each $k \in \{R, B, S, RF\}$, the household problem is characterized by the following Bellman equation, where β is the discount factor, and the set of constraints listed below. Formally,

$$V_j^k(z, x, h, m) = \max_{c,s,h',m',b'} U_j(c, s) + \beta W_{j+1}(z', x', h', m')$$

where

$$W_{j+1}(z', x', h', m') = \begin{cases} \mathbb{E}\left[V_{j+1}(z', x', h', m')\right] & \text{if } j < J_{ret} \\ \phi_j \mathbb{E}\left[V_{j+1}(z', x', h', m')\right] + (1 - \phi_j) U^B(q') & \text{otherwise} \end{cases}$$

subject to

$$\underbrace{c + b' + \mathbb{I}^R p_r s + \mathbb{I}^B (1 + \varsigma^b) p_h h' + \mathbb{I}^{RF,S} (1 - \varsigma^s) p_h h + \mathbb{I}^{RF} \varsigma^r}_{\text{“Expenditures”}} \leq \underbrace{x + m'}_{\text{“Money to spend”}} \tag{3.9}$$

$$\begin{aligned}
&\mathbb{I}^{B,RF} m' \leq (1 - \theta) p_h h' && \text{LTV constraint} \\
&\mathbb{I}^{B,RF} \left(\frac{\chi_{j+1} m' + (\tau^h + \tau^I) p_h h'}{z} \right) \leq \psi && \text{PTI constraint} \\
&\mathbb{I}^S m' \leq (1 + r_m) m - \chi_j m && \text{Min payment} \\
&s = h' && \text{if } h' > 0 \\
&m' \geq 0 && \text{if } h' > 0 \\
&m' = 0 && \text{if } h' = 0 \\
&c > 0, s \in S, h' \in H, b' \geq 0.
\end{aligned}$$

Equation (3.9) states the household's budget constraint. The variables $\mathbb{I}^k$ are indicator variables that equal one for the relevant tenure status case $k \in \{R, B, S, RF\}$, and zero otherwise. These capture that only renters pay rent, only refinancers pay the refinancing cost, and only if you buy or sell a house do you pay the associated transaction costs. In addition, only buyers and households who refinance have to comply with the LTV and PTI requirements, while other homeowners have to adhere to the minimum payment requirement of the amortization schedule. The solution to the household problem is given by

$$\begin{aligned} V_j(z,x,h,m) = \max\Big\{ & V_j^R(z,x,h,m), V_j^B(z,x,h,m) \\ & V_j^S(z,x,h,m), V_j^{RF}(z,x,h,m)\Big\}, \end{aligned} \tag{3.10}$$

with the policy functions that maximize the Bellman equation for the chosen discrete tenure status

$$\Big\{c_j(z,x,h,m), s_j(z,x,h,m), h_j'(z,x,h,m), m_j'(z,x,h,m), b_j'(z,x,h,m)\Big\}.$$

3.2.2 Rental market

There is a unit mass of homogeneous rental firms f that operate in a competitive market with free entry and exit. Rental firms offer rental housing to households, and are owned by foreign investors. The required rate of return of the investors is equal to the return on risk-free bonds r. The competitive rental rate p_r for a unit of rental housing is given by the user-cost formula,

$$p_r = \frac{1}{1+r}\Big[rp_h + \delta^r + \tau^h p_h\Big]. \tag{3.11}$$

Hence, the rental rate is such that it covers the cost of capital rp_h, the maintenance cost of the rental property δ^r, where $\delta^r > \delta^h$, and the property taxes $\tau^h p_h$.[8] Since the operating expenses are realized in the next period, these costs are discounted at the required rate of

[8]The assumption that rental property requires higher maintenance costs than owned housing is motivated by the potential moral hazard problem of rental housing. This is also a common feature of housing models to generate a benefit of owning compared to renting a house (see, e.g., Piazzesi and Schneider (2016)).

return of the investors.

3.2.3 Government

The main role of the government in the model is to tax households and rental firms, and provide social security benefits to those in retirement. Overall, the government runs a surplus, which it spends on activities that do not affect the other agents in the economy.

The government collects property taxes from the rental firms, and taxes the households using three different taxes, as described in equation (3.8). The labor income tax is modeled using a non-linear tax and transfer function $T(\tilde{y})$, as in Heathcote et al. (2017). This function is continuous and convex, and is meant to proxy for the progressive federal earnings taxes in the U.S.

$$T(\tilde{y}) = \tilde{y} - \lambda \tilde{y}^{1-\tau^p}, \tag{3.12}$$

where λ governs the level of the income tax, and τ^p controls the degree of progressivity. The argument $\tilde{y}$ is taxable labor income, which consists of labor income or social security benefits, net of deductions. If beneficial, a household deducts mortgage interest payments and property taxes before paying labor income taxes. Thus, we include some of the main features of the U.S. tax code with respect to housing; that is, imputed rents are not taxed, mortgage interest payments and property taxes are tax deductible, and labor income after deductions is subject to a progressive tax schedule.

3.3 Calibration

The model is calibrated to the U.S. economy. As our aim is to capture a steady state of the economy, we conduct the calibration using long-run averages of parameter values and moments. As this class of models has a hard time matching the strong skewness in wealth that we see in the data, we choose to focus on the bottom 90 percent of the population in terms of net worth. In this paper, we are interested in how households' consumption responses to shocks are affected by different policies in the mortgage and housing markets. Households with very high levels of wealth are likely to be unconstrained in their spending, and their responsiveness to shocks will presumably not depend much on frictions in mortgage and housing markets. Thus, restricting our attention to the bottom 90 percent of the wealth distribution should not materially affect our findings.

3.3.1 Independently calibrated parameters

Most of the parameters are calibrated independently, either computed from data or taken directly from other studies. These parameters are listed in Table 3.1. In the next section, we move on to estimate the remaining parameters using simulated method of moments.

Parameter	Description	Value
σ	Coefficient of relative risk aversion	2
τ^{ss}	Social security tax	0.153
τ^{h}	Property tax	0.01
r	Interest rate, bonds	0
r^{m}	Interest rate, mortgages	0.036
θ	Down-payment requirement	0.10
ψ	Payment-to-income requirement	0.28
δ^{h}	Depreciation, owner-occupied housing	0.03
ς^{I}	Home insurance	0.005
ς^{b}	Transaction cost if buying house	0.025
ς^{s}	Transaction cost if selling house	0.07
R	Replacement rate for retirees	0.5
B^{max}	Maximum benefit during retirement	60.4

Table 3.1: Independently calibrated parameters, taken from the data and other studies

Note: Where relevant, the parameter values are annual. The maximum benefit during retirement B^{max} is stated in 1000's of 2018 dollars.

Demographics and preferences

Households enter the model economy at age 23. At age 65, all households retire, and by age 83 all households have exited the economy. Before retirement, households do not face a risk of dying, but in between age 65 and 82 the probability of surviving to the next period ϕ_j is taken from the Life Tables for the U.S., social security area 1900-2100, for males born in 1950 (see Bell and Miller (2005)).

The coefficient of relative risk aversion σ in the utility function is set to 2, in line with much of the literature. The age-dependent utility shifter e_j, which captures how household size changes with the life cycle, is calibrated from the Panel Study of Income Dynamics (PSID), survey years 1970 to 1992. Specifically, we estimate e_j with a regression of family size on a third-order polynomial of age, and then take the square root of the predicted values.

Taxes

Based on Harris (2005), the social security tax τ^{ss} is set to 15.3 percent of earnings, which corresponds to the total payroll tax for both employers and employees. The property tax rate τ^h is taken from the 2009, 2011, and 2013 waves of the American Housing Survey (AHS). The median real estate tax as a share of the housing value is approximately 1 percent.

Bonds, housing and mortgages

Using yearly data from 1997 to 2013 on 3-month Treasury bill rates, deflated by the Consumer Price Index (CPI), the mean real rate is 0.06 percent.[9] The interest rate on risk-free bonds is therefore set to

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[9] We use data from the Federal Reserve Bank of St Louis of the 3-month Treasury bill rate from the secondary market, seasonally adjusted, and the CPI data is the U.S. city average CPI for all urban consumers, all items.

zero. The average real interest rate on long-term mortgages for the same period is equal to 3.6 percent. This is computed from the Federal Reserve's series of the contract rate on 30-year fixed-rate conventional home mortgage commitments, deflated by the CPI. Hence, we choose a yearly mortgage interest rate of 3.6 percent.

Between 1976 and 1992, the average down payment of first-time buyers in the U.S. ranged from 11 to 21 percent of the house value (U.S. Bureau of the Census, Statistical Abstract of the United States (GPO), 1987, 1988, and 1994). We use the lower bound of this interval, and set the down-payment requirement θ for new mortgages to 10 percent, as this helps us capture the upper tail of the LTV distribution. The payment-to-income requirement ψ is set to 0.28, consistent with Greenwald (2018). The depreciation rate of owned housing is taken from Harding et al. (2007) who estimate the median depreciation rate of owned housing, gross of maintenance, to be 3 percent. The transaction costs for buying and selling a house are set to 2.5 and 7 percent of the house value, respectively. These values are taken from Gruber and Martin (2003). The home insurance rate ς^I is set to 0.005 percent of the house value, which is roughly in line with the median property insurance payment in the 2013 AHS.

Initial assets

To match the distribution of wealth and the correlation between earnings and wealth among the young, we distribute initial assets a to the newborn cohort in the model similarly to Kaplan and Violante (2014). In the model, we divide newborns into 21 equally-sized groups based on their earnings. The probability of being born with initial assets and the amount of these assets vary across earnings bins. These probabilities and amounts are estimated based on data from the Survey of Consumer Finances (SCF). Specifically, we divide households of age 23-25 in the SCF for survey years 1989 to 2013 into 21 equally-sized groups based on their reported earnings. We assume that a household has positive initial assets in the data whenever its asset holdings are larger than 1,000 in 2013 dollars. Within each earnings bin, we then compute the share of households that meet this requirement and the median net worth of these households. For each bin, we scale the median net worth by median earnings for the working-age population in the data. We rescale by median earnings in the model when we allocate the initial assets to households in the model economy.

Labor income

The labor income process is inspired by Cocco et al. (2005). There is an age-dependent and a household-specific component of earnings. Further, households of working age face permanent and transitory earnings risk, while households in retirement only experience transitory shocks to their social security benefits. The estimation of the earnings process is described in detail in Appendix 3.C.

Log earnings for household i of age j are given by

$$\log(y_{ij}) = \alpha_i + g(j) + n_{ij} + \nu_i \quad \text{for } j \leq J_{ret}, \tag{3.13}$$

where α_i is the household fixed effect, distributed $N(0, \sigma_\alpha^2)$, and $g(j)$ is the age-dependent component of earnings, which captures the hump-shaped life-cycle profile. n_{ij} is an idiosyncratic random-walk component, which evolves according to a permanent income shock η_{ij}, distributed $N(0, \sigma_\eta^2)$. The household also draws an i.i.d. transitory shock ν_i, distributed $N(0, \sigma_\nu^2)$, which is uncorrelated with the permanent earnings shock. The log of the permanent earnings state z_{ij} in the model is given by the sum of the household-fixed component, the age-dependent component of earnings, and the random-walk component, i.e., $\log(z_{ij}) = \alpha_i + g(j) + n_{ij}$.

The social security benefits in retirement are given by a fixed proportion R of permanent earnings in the period before retirement, subject to a cap B^{max}. The common replacement rate R is taken from Díaz and Luengo-Prado (2008) and is set to 50 percent, whereas B^{max} is computed from Social Security Administration data. Further, the benefits are affected by transitory shocks, drawn from the same distribution as the transitory earnings shocks. Formally,

$$\log(y_{ij}) = \min\left(\log(R) + \log(z_{i,J_{ret}}),\ \log(B^{max})\right) + \nu_i \quad \text{for } j > J_{ret}. \tag{3.14}$$

To estimate equation (3.13), we use PSID data from the survey years 1970 to 1992. In the estimation of the age-dependent components of earnings $g(j)$, we follow Cocco et al. (2005). We estimate the variances of the permanent and transitory shocks as in Carroll and Samwick (1997). The variance of the fixed-effect shock is estimated as the residual variance in earnings of the youngest cohort, net the deterministic trend value and the variances of the permanent and the transitory shocks. The estimated variances of the earnings shocks are displayed in Table 3.2.

Parameter	Description	Value
σ^2_α	Fixed effect	0.156
σ^2_η	Permanent	0.012
σ^2_ν	Transitory	0.061

Table 3.2: Estimated variances of earnings shocks
Note: Household earnings contain a fixed household component. Throughout working life, earnings are subject to permanent and transitory shocks, while in retirement there is only transitory earnings risk. Estimated with PSID data, years 1970 to 1992.

3.3.2 Estimated parameters

The parameters that are estimated to match a set of data moments are listed in Table 3.3. Unless otherwise noted, we use data from the SCF, pooled across the 1989 to 2013 survey years. All parameters in Table 3.3 are jointly estimated, taking the independently calibrated parameters in Table 3.1 as given.[10]

Parameter	Description	Value	Target moment	Data	Model
α	Consumption weight in utility	0.80	Median house value-to-earnings, age 23–64	2.26	2.26
β	Discount factor	0.956	Mean net worth, over mean earnings age 23–64	1.38	1.38
υ	Strength of bequest motive	5.60	Net worth mean age 75 over mean age 50	1.64	1.64
δ^r	Depreciation rate, rentals	0.076	Homeownership rate, age 23–35	0.44	0.44
$\underline{\mathrm{h}}$	Minimum owned house size	199	Homeownership rate, all ages	0.67	0.67
ς^r	Refinancing cost	2.77	Refinancing share, homeowners	0.08	0.08
λ	Level parameter, tax system	1.69	Average marginal tax rates	0.13	0.13
τ^p	Progressivity parameter	0.14	Distribution of marginal tax rates	N.A.	N.A.

Table 3.3: Estimated parameters
Note: Parameters estimated using simulated method of moments. The first two columns list the parameters and their descriptions. The third column shows the estimated parameter values. The fourth column contains the descriptions of the targeted moments, while column five lists their respective values in the data. Finally, the last column states the values of the corresponding model moments, achieved by using the parameter values in column three. The minimum owned house size $\underline{\mathrm{h}}$ and the fixed refinancing cost ς^r are in 1000's of 2018 dollars.

The consumption weight in the utility function α controls the share of expenditures that is allocated to consumption versus housing services. This weight is set to 0.80 to match the median house value-to-earnings ratio, among the working-age homeowners. The discount factor β affects the savings decisions. It is therefore used to match the mean net worth over mean earnings, among households of age 23 to 64. The resulting yearly discount factor is 0.956. To capture the strength of the bequest motive, the utility shifter of bequests υ is used to match the mean net worth of households aged 75 over the mean net worth of households aged 50. The parameter value is estimated to be 5.60.

The decision to buy a house instead of renting housing services is affected by a number of factors in the model. Abstracting from frictions in the mortgage and housing markets, households generally prefer to own. This positive net benefit of owning is partly due to the

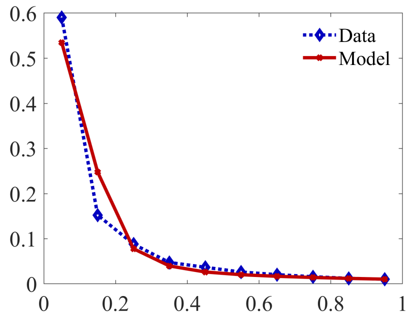
[10]When we solve the baseline model, the housing supply is chosen such that the price of a unit of owned housing is equal to the price of a unit of consumption, i.e., $p_h = 1$. In turn, the rental rate is given by equation (3.11). See the Appendices for a detailed description of the solution method and the equilibrium definition.

preferential tax treatment of owned housing, i.e., mortgage interest payments and property taxes are tax deductible and imputed rents are left untaxed. However, because there are frictions in the mortgage and housing markets, an additional benefit of owning is required to incentivize households to buy when they are young. Therefore, we estimate the depreciation rate of rental housing δ^r to match the homeownership rate among young households, aged 23 to 35. The depreciation rate needed to meet this target is 7.6 percent. The minimum house size available for purchase $\underline{\mathrm{h}}$, which is strictly larger than the minimum house size available for rent, is set to match the overall homeownership rate in the data. To capture the liquidity of housing equity, we estimate the fixed refinancing cost ς^r. With a cost slightly below $2,800$ in 2018 dollars, we match the 8 percent refinancing rate among homeowners as stated in Chen et al. (2020).

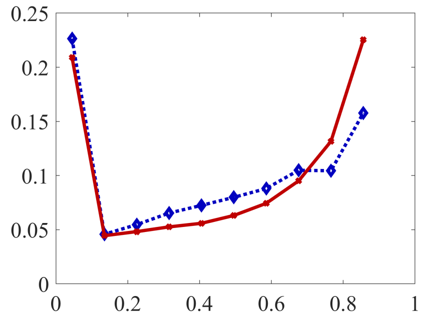
The two parameters of the tax and transfer function $T(\tilde{y})$ are estimated to match the level and the progressivity of earnings taxes in the U.S. The level parameter λ is set to 1.69, to match the average marginal earnings tax rate after deductions among the working-age population. The progressivity of the earnings tax is controlled by parameter τ^p. This parameter is set to 0.14, to minimize the sum of the absolute difference between the fraction of households exposed to the different statutory tax brackets in the data compared to the model. Since the tax schedule is continuous in the model, households are allocated to their nearest tax bracket in the data for this calibration exercise. The data on tax rates is taken from Harris (2005).

3.3.3 Data versus model: distributions

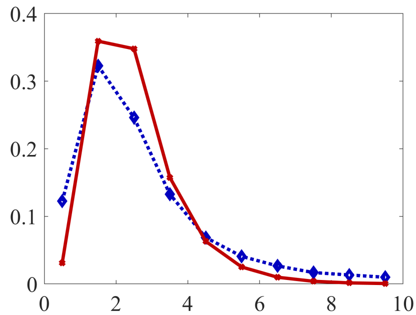
At the heart of our research question is the need for the model to capture the extent to which households are constrained. Households may be constrained in their spending if they have low levels of liquid bond savings. How constrained a homeowner is also depends on



(a) Distribution, liquid savings-to-earnings

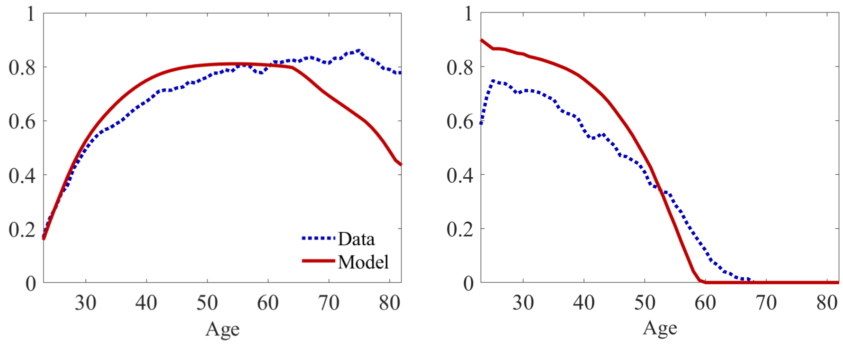


(b) Distribution, loan-to-value



(c) Distribution, house value-to-earnings

Figure 3.1: Comparison of data versus model: non-targeted distributions
Note: The data is from the SCF, survey years 1989-2013. The model refers to the baseline economy. In Figure 3.1a and Figure 3.1c, only working-age households are included, and Figure 3.1b only displays homeowners.



(a) Homeownership rate **(b)** Median LTV

Figure 3.2: Comparison of data versus model: non-targeted life-cycle profiles

Note: The data is from the SCF, survey years 1989-2013. The model refers to the baseline economy. The median LTV is computed among homeowners.

how much equity is available in the house, and if increased mortgage financing is possible. In Figure 3.1, the distributions of liquid savings-to-earnings, LTVs, and house value-to earnings are shown for the model and for data from the SCF.[11] Further, the life-cycle profiles of LTV and homeownership inform us about who the constrained homeowners are. Housing and mortgage choices are tightly linked to the age of households, as seen in Figure 3.2.

3.4 Results

Equipped with our model, we now turn to the quantitative analysis. We start by carefully analyzing the determinants of MPCs in our

[11]We define liquid savings in the SCF as the sum of cash, checking, savings, money market, and call accounts, prepaid cards, directly-held mutual funds, stocks, and bonds, less any credit card debt balance. Cash is assumed to be five percent of the balance in the variable *liq* in the SCF, similar to Kaplan and Violante (2014). We define net worth to be the sum of liquid savings and housing wealth less mortgages.

baseline model. Then, we consider how permanent and temporary changes in LTV and PTI requirements affect individual and aggregate consumption responses to wealth shocks. In the case of temporary policies, we complement the analysis by solving for optimal policies and investigate how they vary depending on the magnitude of the wealth shocks.

We define the marginal propensity to consume for household i of age j as

$$MPC_{ij} \equiv \frac{c_{ij}(z, x + \Delta_x, h, m) - c_{ij}(z, x, h, m)}{\Delta_x}, \tag{3.15}$$

where $c_{ij}(z, x, h, m)$ is consumption for household i of age j if there is no shock, and $c_{ij}(z, x + \Delta_x, h, m)$ is consumption when there is a shock of size Δ_x. Intuitively, the MPC is the fraction of the shock Δ_x that is spent on non-housing consumption. The unexpected change in cash-on-hand Δ_x is referred to as a wealth shock. This shock is meant to capture a change in available resources that could stem from various sources, such as unexpected changes in asset prices or labor income.[12]

As more stringent lending standards are often introduced to alleviate the costs of large shocks in the economy, Δ_x will take on sizable values in our experiments. When subject to larger shocks, some households may want to change their discrete tenure choice. We refer to these households as *switchers*, whereas households who do not change their discrete choice are referred to as *non-switchers*. For example, a household is a switcher if it were to have been a renter, but chooses to become a homeowner due to the wealth shock.

[12]We think of a negative wealth shock as representing an economic downturn, though admittedly a stylized one.

3.4.1 Dissecting MPCs in a housing model

Before we study the impact of stricter mortgage lending standards, it is useful to understand the underlying determinants of MPCs in the model. We begin by showing the MPCs of a negative wealth shock of $1,000$ dollars.[13] Later, we also explore how the MPC varies with the sign and magnitude of the shock.

Figure 3.3 shows that there is considerable heterogeneity in MPCs across households. At the right-hand tail, there is a large group of households that have an MPC of one, and thus reduce their spending one-for-one with the fall in cash-on-hand. They are so-called hand-to-mouth households. In contrast, other households increase their non-housing consumption in response to the negative shock, which implies that their MPCs are negative. In between these extremes, there is a significant mass over the whole support.

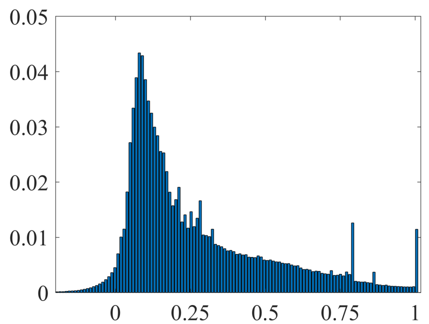


Figure 3.3: Distribution of MPCs
Note: Wealth shock of $-1,000$ dollars.

To gain further intuition about the distribution of MPCs, we first consider three groups of non-switchers, i.e., those who do not change their discrete choice in response to the shock. The first group consists of *renters*. We call the second group *constrained owners*, which we

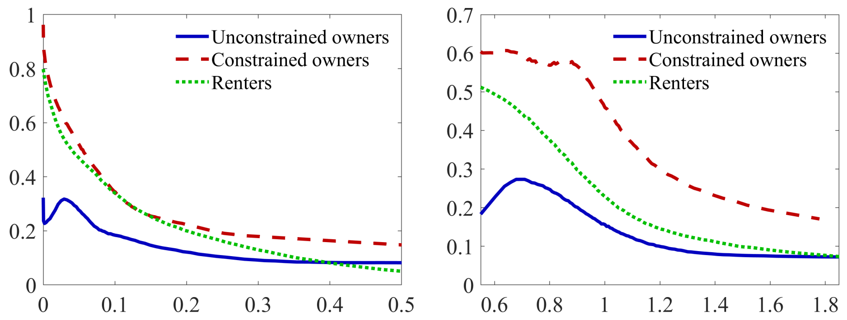
[13] Hereafter, dollars refer to 2018 dollar value.

define as owners who choose an LTV above 0.8 and/or follow the mortgage repayment plan in the absence of the wealth shock. The last group, *unconstrained owners*, comprises households who choose an LTV below 0.25 and a mortgage level below that implied by the amortization plan in the case when there is no shock. Clearly, there are households that do not fall into either of these groups. The chosen groups are only meant to illustrate the key determinants of MPCs.

Figure 3.4a shows how MPCs depend on the ratio of liquid savings to earnings that households would choose if there was no shock. Naturally, households that expect to hold considerable amounts of liquid bonds are better prepared to handle negative shocks and thus have lower MPCs. For renters and constrained owners, lower bond holdings signal that these households were already constrained before the shock. When hit by a negative wealth shock, they respond by decreasing non-housing consumption. Renters with no savings (poor hand-to-mouth) rent in a frictionless rental market, so their drop in non-housing consumption equals the consumption expenditure share $\alpha \approx 0.8$. This explains the spike around 0.8 in Figure 3.3. Constrained owners, with low levels of liquid savings (wealthy hand-to-mouth), cannot freely access their housing equity. As a consequence, they respond by reducing non-housing consumption and have MPCs around one. These households thus comprise the right-hand tail in Figure 3.3. The MPCs of unconstrained owners remain relatively moderate even for low levels of liquid assets-to-earnings. These households expect to pay off more on their mortgage than what is stipulated by their amortization plan, and can thus adjust by paying off less in response to the shock.

In Figure 3.4b, we show that households with a higher transitory income tend to have lower MPCs. This observation complements the findings in Figure 3.4a. Households with a high transitory income component are more likely to save in order to smooth consumption over time. Thus, when hit by a negative wealth shock, these households have the possibility to save less than planned. Households with a low transitory shock are relatively poor today and expect higher earnings in the future. Therefore, they want to save little to begin with, and respond strongly to the negative wealth shock by consuming less. Again, the MPC of unconstrained owners is generally lower.

A key feature of Figure 3.3 that we have not discussed thus far is the large portion of households with an MPC of around 0.1. Our results in Figure 3.4a and Figure 3.4b indicate that these are households with a high transitory income and/or those who can use their liquidity buffer to cushion the negative wealth shock. Thus, these households are fairly unconstrained in their spending.



(a) MPC across liquid savings-to-earnings

(b) MPC across transitory earnings

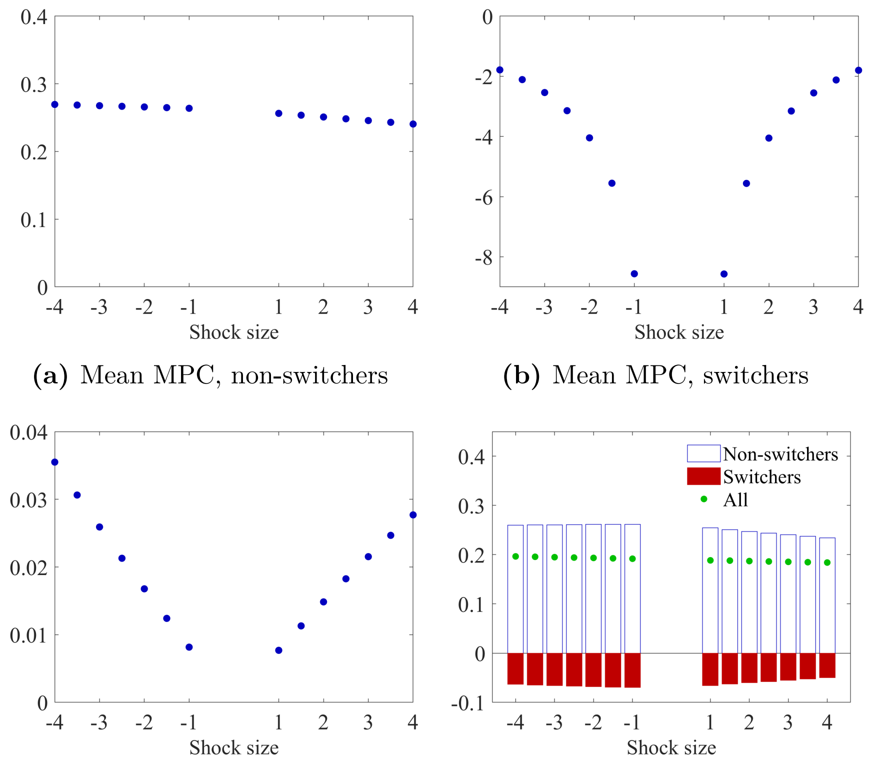
Figure 3.4: Decomposing the mean MPC of non-switchers
Note: MPCs for working-age households from a wealth shock of $-1,000$ dollars

The households who change their discrete choice, i.e., the switchers, behave quite differently from the non-switchers described above. Almost all switchers have sizable negative MPCs, most of them much lower than what is shown in Figure 3.3. On average, their MPC is approximately -8. As the group of switchers account for less than one percent of the population in the case of a wealth shock of $-1,000$ dollars, the mean MPC in the economy is still relatively high and equal to 0.19.

For a negative wealth shock, there are two important groups of switchers. The first group consists of households who choose to abstain from buying a house due to the shock. These households are, on average, younger and have a lower income than other buyers. Although their total spending may decrease due to the wealth shock, their non-housing consumption increases as they avoid paying the down payment and the transaction cost of buying. Out of all households that would buy a house in the absence of the wealth shock, 4.1 percent of them decide not to.

The second group of switchers comprises households who choose to refinance their mortgage instead of following their amortization plan, due to the negative wealth shock. They have illiquid housing wealth that they access by paying the refinancing cost. As the refinancing cost is sizable, it only makes sense for households in dire need of liquidity to pay the cost. Households who choose to refinance, due to the shock, only make up one percent of all initial stayers, and they tend to have a low transitory income. Once these households access their housing equity, they significantly increase their consumption.

In Figure 3.5, we decompose the effects of non-switchers and switchers for the mean MPC across shock sizes. Figure 3.5a shows that the average MPC of non-switchers is close to 0.3 for most shocks, although the MPC is falling somewhat for larger positive shocks as households become increasingly unconstrained. Clearly, the MPC of switchers, as depicted in Figure 3.5b, differs remarkably from that of non-switchers. For smaller wealth shocks, the MPC is very low. As the shocks become more significant, the MPC becomes less negative. When households change a discrete choice, this leads to a jump in non-housing consumption. Contingent on switching, the absolute size of the jump in consumption largely depends on the level of the down-payment requirement and the transaction costs of buying and refinancing. For example, the savings from not paying the down payment and the transaction cost of buying do not depend on the shock size, for a household who abstains from buying. The lower the transaction costs are, the lower is the change in consumption.[14]



(a) Mean MPC, non-switchers **(b)** Mean MPC, switchers

(c) Share who switches **(d)** Mean MPC, all

Figure 3.5: Decomposing the mean MPC across shock size (thousands of dollars)
Note: Switchers are those who change their discrete choice in response to a shock.

Despite that the average MPC of switchers is sensitive to the shock

[14]See Appendix 3.D.1 for a comparison of the average MPCs of switchers in a setting where there are no refinancing costs or no transaction costs for buying and selling a house.

size, Figure 3.5d shows that the mean MPC among all households is close to 0.19 for the range of shock sizes we consider. There are two reasons for this result. First, the fraction of switchers increase in the magnitude of the wealth shock, as seen in Figure 3.5c. Thus, even if the MPC of switchers becomes less negative for larger shocks, the extensive margin acts as a counter weight. Second, the fraction of switchers grows faster for negative than for positive wealth shocks. This off-sets the slight fall in MPCs among non-switchers as the shock becomes larger and positive.

3.4.2 Permanent changes in LTV and PTI

As shown in the previous section, there is a significant heterogeneity in MPCs, which arises due to costs and constraints in the housing and mortgage markets. Constrained homeowners are among the households with particularly high consumption responses to wealth shocks. Their debt levels are considerable and they generally have a limited access to liquid funds. As such, policymakers may find it reasonable to introduce stricter lending requirements. After all, higher debt levels are associated with higher MPCs.

A natural argument against stricter requirements is that they strengthen the financial frictions in the economy. By making it more difficult to borrow, the ability to smooth consumption in response to a wealth shock may worsen, causing an increase in MPCs. Moreover, one has to take into consideration the behavioral responses by households. The distribution of asset holdings is bound to change in response to new regulatory requirements. For example, a household that chooses to hold less debt due to a stricter LTV requirement may also choose to hold less liquid bonds now that it has more housing equity. Ultimately, the question of how mortgage lending standards affect consumption dynamics requires a quantitative analysis.

In this section, we study how the aggregate consumption response to a wealth shock and the distribution of MPCs across households change as a result of tougher LTV and PTI regulations. To quantify the effects of stricter policies on MPCs, we consider two relatively large changes. In the first experiment, we consider a permanent tightening of the LTV limit from 0.9 to 0.7. In the second experiment, the PTI requirement is 0.18 instead of the baseline value of 0.28. In both experiments, we solve for a new steady state, where we allow house prices to change under the assumption that the aggregate housing stock is fixed.[15]

The policies we consider impact the model economy in several important ways. Table 3.4 shows steady-state prices and moments across policies. When stricter regulations are in place, it is more difficult for households to buy houses. As a result, the homeownership rate is lower. Unsurprisingly, the policies reduce the average loan-to-value ratios in the economy. The mean net worth over mean earnings remains relatively stable, although it increases somewhat in the case of stricter LTV. In general, the LTV policy leads to larger changes in steady-state moments as compared to the PTI policy, even if the price effects are similar.

	Baseline	Stricter LTV	Stricter PTI
Max LTV	0.90	0.70	0.90
Max PTI	0.28	0.28	0.18
House price	1	0.965	0.959
Rent	0.086	0.086	0.086
Homeownership rate	0.674	0.605	0.647
Median house-to-earnings ratio	2.259	2.164	2.134
Mean net worth age 75 over 50	1.637	1.401	1.633
Median loan-to-value ratio	0.339	0.147	0.250
Mean net worth, over mean earnings	1.381	1.477	1.379
Mean liquid savings-to-earnings	0.752	0.765	0.765

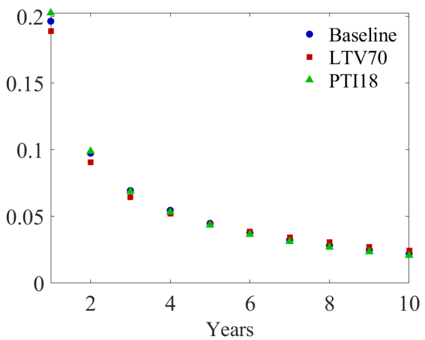
Table 3.4: Steady-state prices and moments under permanent changes in lending policies

[15] The pair of policies was chosen such that the percentage change in house prices is roughly the same.

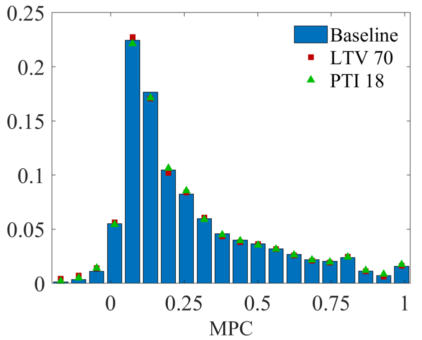
Although the debt levels are substantially reduced, the aggregate consumption response to wealth shocks and the distribution of MPCs are largely unaffected by the permanently stricter LTV and PTI policies. Figure 3.6a shows the aggregate consumption dynamics up to 10 years after a wealth shock of $-4,000$ dollars.[16] There are virtually no differences in the dynamics across policies. In Appendix 3.D.2, we show that this result holds for shock sizes of varying magnitudes and is independent of the sign of the shock. Moreover, Figure 3.6b shows that the distributions of MPCs are almost identical under all policies. These results are also robust to considerably larger changes in policies. A permanent change in the LTV limit to 0.5 or the PTI constraint to 0.1 produces very similar MPCs to those of the baseline model, as seen in Appendix 3.D.2. As there are no large changes in the distributions, there are also no significant changes in the role of switchers and non-switchers in the case of permanently stricter lending standards, see Appendix 3.D.2.

Overall, the behavioral responses of households are crucial for understanding why permanently stricter lending standards have such a small impact on MPCs. When considering permanent policies in steady state, households are free to re-optimize, taking into account the new regulatory environment. How much households save in liquid assets is driven by their desire to insure against negative earnings shocks. The amount of precautionary savings is governed by deep parameters, e.g. the risk-aversion parameter σ, rather than lending standards set by the government. As such, there are only small differences in liquid bond holdings across policies, as indicated by the mean liquid savings-to-earnings ratio in Table 3.4.

[16] We assume that the shock is unexpected. To focus on the direct demand effect, we assume that prices are constant during the transition.



(a) Mean MPC over time



(b) Distribution of MPCs in $t = 1$

Figure 3.6: MPCs for different permanent policies
Note: MPCs from a wealth shock of $-4,000$ dollars in $t = 1$. In the baseline model, the LTV limit is 90 percent and the PTI constraint is 28 percent.

3.4.3 Temporary changes in LTV and PTI

Can temporary changes in LTV and PTI affect consumption responses?

A key conclusion from the previous section is that permanent policies appear to have a limited ability to affect consumption responses to wealth shocks. We now move on to analyze whether temporary policies can more effectively impact households' MPCs. Just like in the analysis of permanent policies, we begin by studying a wealth shock of $-4,000$ dollars. We let this wealth shock occur in time period $t = 2$. The shock is not expected by households, but we make the strong assumption that a hypothetical regulatory authority has perfect foresight. In an attempt to cushion the negative consumption response in $t = 2$, a stricter credit policy is enforced in $t = 1$, but then returns to its baseline value in $t = 2$. The policy is unexpectedly implemented in $t = 1$, but households know with certainty that the lending standards will be back to normal in the next period.

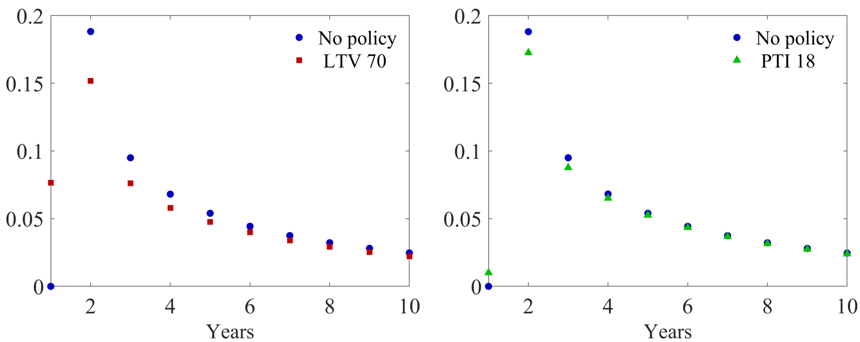
The main role of the temporary policy is to reallocate consumption over time. Since we abstract from price changes in this part of the analysis, cumulative consumption over time will be largely independent of whether there is a policy in place or not. Thus, the temporary policy may only be effective at dampening the consumption response in $t = 2$ if it can lower the spending in $t = 1$.

Qualitatively, the aggregate consumption effect in $t = 1$ is ambiguous. The policy affects households who would otherwise choose larger mortgages than what is allowed under the new policy. Thus, only households who refinance or buy a house in the absence of the policy are potentially affected. The group of households who would refinance without the policy lower their consumption in response to the policy for two reasons. First, households who refrain from refinancing cut back on consumption as they no longer extract any housing equity. Second, those who continue to refinance also need to reduce their consumption as the amount of equity extraction is restricted by the policy. Furthermore, households who continue to buy a house need to finance their home with more equity and thus decrease consumption. Households who abstain from buying a house, however, increase their consumption since they no longer have to finance the down payment or pay any transaction costs.

Quantitatively, the consumption responses in $t = 2$ are dampened as a result of the temporary stricter lending standards. Figure 3.7a compares the consumption dynamics of the baseline model where there is no policy change to the case where the LTV limit is lowered to 0.7 in $t = 1$. Contrary to the results for permanent policies, the aggregate MPC out of the negative wealth shock is considerably reduced on impact ($t = 2$), and stays below the no-policy case for several years. The muted consumption response is made possible as the temporary stricter LTV requirement makes households cut consumption in $t = 1$.[17]

[17]Note that the fall in consumption in $t = 1$ shows up as a positive MPC in the figure, as the consumption response is normalized by the negative wealth shock.

Figure 3.7b shows that a temporary change in the PTI limit can also reduce the consumption response in $t = 2$, although this policy appears somewhat less effective at achieving this goal. It is important to note, however, that it is also possible to get strong consumption responses from a temporary change in PTI. In results that we do not report, a temporary change in the PTI requirement to 0.1 leads to consumption responses that are quantitatively similar to reducing the LTV limit to 0.7.



(a) Mean MPC over time **(b)** Mean MPC over time

Figure 3.7: MPCs for different temporary LTV and PTI policies
Note: Consumption responses under a temporary stricter policy in $t = 1$, that is reversed in $t = 2$. Unexpected wealth shock of $-4,000$ dollars in $t = 2$. The consumption responses are normalized by $-4,000$ dollars also in $t = 1$, where there is only a change in policy and no shock has occurred. In the baseline model with no temporary policy, the LTV limit is 90 percent and the PTI constraint is 28 percent.

Can temporary policies be welfare improving?

Although temporary policies may successfully dampen the consumption response to a negative wealth shock, it is not obvious whether and under what circumstances temporary policies improve welfare. On the one hand, households may benefit from the policy as it makes them increase their savings, thus making them better prepared to face the wealth shock. On the other hand, any fall in consumption in $t = 1$

reduces welfare in that period. Also, households may already save sufficiently for precautionary reasons. If the policy makes households save more than necessary, it has a negative impact on welfare.

To better understand the welfare implications of temporary lending policies, we solve for optimal LTV and PTI requirements in $t = 1$. We define an optimal policy as a policy that maximizes the mean ex-post consumption equivalent variation (henceforth CEV). More specifically, for each household alive at $t = 1$, we compute the per-period percentage change in consumption under the no-policy scenario needed to make the household indifferent between a policy and no policy. Our welfare measure is then the mean of these household-specific CEVs.[18] We do not consider policies that are more lenient than the benchmark lending requirements.

We find that temporary policies can be optimal, but only if the bust is sufficiently large. For example, the optimal policy for the wealth shock of $-4,000$ dollars is to keep lending standards at baseline levels throughout. However, when we consider a more extreme case, where all households are exposed to a wealth shock of $-12,000$ dollars, a temporary stricter LTV limit of 0.86 is optimal.[19] Yet, it continues to be optimal to leave the PTI requirement untouched at 0.28.

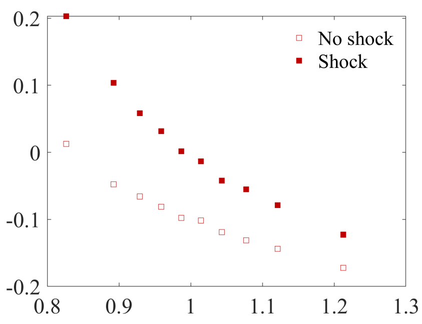
At the optimal LTV level, the mean MPC in the bust period is only slightly reduced and the average welfare gain is small. The nearly negligible changes in aggregate consumption dynamics are shown in Appendix 3.D.3. In terms of welfare, we find that the mean CEV is 0.0004 percent under the optimal LTV policy.

One reason for the small average welfare effect is that a vast majority of households are unaffected by the policy, and thus have a

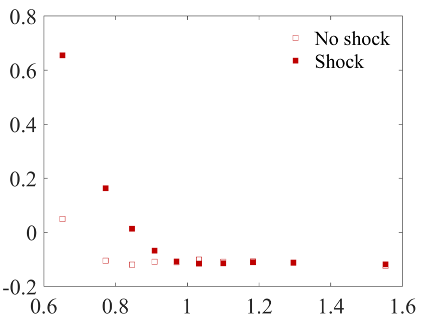
[18] A more thorough description of the welfare measure is provided in Karlman et al. (2020).

[19] As this shock is very large, we assume that no household can end up with a cash-on-hand lower than the lowest grid point used in the baseline calibration. This corresponds to about $1,800$ dollars.

CEV of zero. The welfare effects can be substantial at the household level. Figure 3.8 shows the mean CEV across labor income shocks in $t = 2$, for a temporary LTV policy of 0.86. We limit the sample to only include households that change their mortgage decision in response to the policy change. The filled markers correspond to the welfare effects of introducing the policy when an unexpected shock of $-12,000$ dollars follows, whereas the hollow markers indicate the welfare effects of implementing the policy when there is no shock.



(a) CEV across permanent income



(b) CEV across transitory income

Figure 3.8: Mean CEV (%) with or without wealth shock in $t = 2$
Note: The figures show the welfare effects of households that are directly affected by a temporary LTV policy of 86 percent in $t = 1$. The markers illustrate the mean welfare effect of ten equally sized groups, ordered by the variable on the x-axis. “No shock” refers to the welfare effects of introducing the policy when no subsequent wealth shock occurs. “Shock” refers to the welfare effects when a wealth shock of $-12,000$ dollars occurs in $t = 2$.

When there is a large bust, the policy is positive for households whose income realization is low. Intuitively, a household with an unlucky income draw in $t = 2$ benefits from the increased savings in $t = 1$. Figure 3.8a shows that households whose permanent income is about 20 percent lower than expected have a mean welfare gain of 0.2 percent. Similarly, Figure 3.8b shows that households with a very low transitory income have a mean welfare gain of more than 0.6 percent. As indicated by the hollow markers in Figure 3.8, the policy is mostly negative for households if there is no bust in $t = 2$.

The welfare costs of a temporary stricter policy can be considerable for households who experience better income draws in $t = 2$, even when the bust is large. These households are simply better equipped to handle the negative wealth shock. Thus, the costs of lower consumption in $t = 1$ outweigh any potential benefit from increased savings.

To shed some further light on the welfare effects, let us once more divide households into groups based on how they respond to the policy change. Recall that the policies only bind for households whose mortgage choice becomes limited by the new policy, i.e., refinancers and house buyers who would choose a larger mortgage absent the policy. Refinancers in $t = 1$ have usually drawn a very low transitory shock and are therefore in need of liquidity already in the first period. As a temporary stricter policy limits the extraction of housing equity in a period where liquid funds are valuable, these households have negative welfare effects on average. Households who continue to buy even after the policy has been introduced are also negatively affected on average. As more equity is needed to buy a house, their consumption drops in $t = 1$. Moreover, when they are hit by the negative wealth shock, they have a large fraction of their wealth in the illiquid housing asset and therefore find it difficult to smooth consumption. The only group that benefits from a temporary stricter policy are households who abstain from becoming homeowners in the boom. They increase their consumption in $t = 1$ and avoid being liquidity constrained in $t = 2$.

What are the effects of alternative shock scenarios?

There are alternative wealth-shock scenarios that are worth exploring. In particular, it can be argued that stricter LTV or PTI policies can be usefully implemented during a boom phase, as an exuberant economy may signal future busts.

To study the effects of including a boom period, we add a positive wealth shock of size Δ_x in $t = 1$, followed by a bust of the same magnitude in $t = 2$.[20] Figure 3.13 in Appendix 3.D.3 shows that temporary stricter LTV and PTI requirements continue to dampen the consumption responses in $t = 1$ and $t = 2$. Yet, for a given strictness of a temporary policy the consumption effect is lower, as the boom phase makes the policy less binding.

We find that the optimal policies are stricter when we consider a pronounced boom-bust episode, as compared to a scenario without a boom phase. For example, when the wealth shocks are of the size $12,000$ dollars, the optimal LTV and PTI policies are 0.8 and 0.18, respectively. Recall that with no boom phase, the optimal limits are 0.86 and 0.28. Why is that? First, during a boom there are fewer households who want to refinance and therefore the number of households who suffer from a stricter policy is lower. In the model, households who refinance often have a low transitory income. As the positive wealth shock in $t = 1$ is similar to receiving a higher transitory income shock, fewer households find it optimal to tap into their housing equity. Second, when the bust is larger, the benefits from making households abstain from buying are greater.

When the boom-bust episode is more muted, the optimal policy is to leave the lending standards unchanged. For example, this is the case if we consider a boom of $4,000$ dollars followed by a bust of $-4,000$ dollars. When the boom is less strong, many households still want to refinance and thus the costs of stricter policies are larger. Furthermore, the benefit of keeping households from buying is reduced as the bust is less severe.

In the above analysis, we assume that the regulatory authority has perfect foresight and knows that there is a bust in $t = 2$. This informational advantage creates a rationale for the government to intervene. Clearly, this assumption is very strong. At the very least,

[20] Admittedly, this example is highly stylized, but it still offers valuable insights into the effects of temporary policies.

we would expect there to be some noise in the government's signal about the future. Therefore, we also consider a case where there is a boom, but that no bust follows. Under this scenario, the optimal policy is to avoid temporary stricter policies. There is little to gain by restricting households from buying if there is no bust. Further, we consider a scenario where not only the policymaker but also the households have information about the coming bust. Also in this case, the optimal policy is to keep mortgage lending standards constant at current levels.

3.5 Concluding remarks

Since the Great Recession, policymakers in many countries have considered and implemented stricter mortgage lending standards. These policies aim at lowering household debt and, ultimately, reducing households' vulnerability to shocks. In this paper, we investigate if households' consumption responses to shocks depend on mortgage lending standards. Specifically, we study two types of policies in the mortgage market: stricter LTV and PTI requirements.

We find that permanently lower LTV and PTI limits reduce the debt level in the economy, but they are unsuccessful in dampening the aggregate consumption response to wealth shocks. In fact, the distribution of MPCs is only marginally affected by the permanently stricter policies. As the underlying incentives to insure against shocks are unchanged, households adjust their asset portfolio such that the more stringent borrowing requirements have little impact on their consumption sensitivity to shocks.

In contrast, we do find that temporary policies can dampen the consumption responses to shocks, but it does not come without any costs. Specifically, we find that LTV and PTI requirements introduced in a period before a downturn reduce the consumption fall during the bust. However, for such policies to be beneficial for households on average, strong assumptions about an informational advantage of the policymaker are needed, and the bust needs to be large.

There are a number of extensions to the analysis that would be worthwhile exploring in future work. First, in our analysis we abstract from propagation mechanisms through changes in prices or output, and focus on the immediate demand response from a wealth shock. A fruitful way forward would be to incorporate additional feedback effects of changes in demand to our framework. Arguably, households' direct endogenous responses to stricter mortgage regulations will be central even in a richer setting. Second, it would be interesting to see whether the results are generalizable to other types of shocks, such as changes to house prices.

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Appendices

3.A Definitions of stationary equilibrium

Households are heterogeneous with respect to age $j \in \mathcal{J} \equiv \{1, 2, ..., J\}$, permanent earnings $z \in \mathcal{Z} \equiv \mathbb{R}_{++}$, mortgage $m \in \mathcal{M} \equiv \mathbb{R}_{+}$, owner-occupied housing $h \in \mathcal{H} \equiv \{0, \underline{\mathrm{h}}, ..., \bar{h} = \bar{s}\}$, and cash-on-hand $x \in \mathcal{X} \equiv \mathbb{R}_{++}$. Let $\mathcal{U} \equiv \mathcal{Z} \times \mathcal{M} \times \mathcal{H} \times \mathcal{X}$ be the non-deterministic state space with $\mathbf{u} \equiv (z, m, h, x)$ denoting the vector of individual states. Let $\mathbf{B}(\mathbb{R}_{++})$ and $\mathbf{B}(\mathbb{R}_{+})$ be the Borel σ-algebras on $\mathbb{R}_{++}$ and $\mathbb{R}_{+}$, respectively, and $P(\mathcal{H})$ the power set of $\mathcal{H}$, and define $\mathscr{B}(\mathcal{U}) \equiv \mathbf{B}(\mathbb{R}_{++}) \times \mathbf{B}(\mathbb{R}_{+}) \times P(\mathcal{H}) \times \mathbf{B}(\mathbb{R}_{++})$. Further, let $\mathbb{M}$ be the set of all finite measures over the measurable space $(\mathcal{U}, \mathscr{B}(\mathcal{U}))$. Then $\Phi_j(U) \in \mathbb{M}$ is a probability measure defined on subsets $U \in \mathscr{B}(\mathcal{U})$ that describes the distribution of individual states across agents with age $j \in \mathcal{J}$. Finally, denote the time-invariant fraction of the population of age $j \in \mathcal{J}$ by Π_j.

Stationary equilibrium, the baseline economy

Definition 1. A stationary recursive competitive equilibrium is a collection of value functions $V_j(\mathbf{u})$ with associated policy functions $\{c_j(\mathbf{u}), s_j(\mathbf{u}), h'_j(\mathbf{u}), m'_j(\mathbf{u}),$
$b'_j(\mathbf{u})\}$ for all j; prices $(p_h = 1, p_r)$; a quantity of total housing stock $\bar{H}$; and a distribution of agents' states Φ_j for all j such that:

1. Given the prices $(p_h = 1, p_r)$, $V_j(\mathbf{u})$ solves the Bellman equation (3.10) with the corresponding set of policy functions $\{c_j(\mathbf{u}), s_j(\mathbf{u}), h'_j(\mathbf{u}), m'_j(\mathbf{u}), b'_j(\mathbf{u})\}$ for all j.

2. Given $p_h = 1$, the rental price per unit of housing service p_r is given by equation (3.11).

3. The quantity of the total housing stock is given by the total demand for housing services[21]

$$\bar{H} = \sum_{\mathcal{J}} \Pi_j \int_U s_j(\mathbf{u}) d\Phi_j(U).$$

4. The distribution of states Φ_j is given by the following law of motion for all $j < J$

$$\Phi_{j+1}(\mathcal{U}) = \int_U Q_j(\mathbf{u}, \mathcal{U}) d\Phi_j(U),$$

where $Q_j : \mathcal{U} \times \mathscr{B}(\mathcal{U}) \to [0, 1]$ is a transition function that defines the probability that a household at age j transits from its current state $\mathbf{u}$ to the set $\mathcal{U}$ at age $j + 1$.

Stationary equilibrium, after a permanent policy change

Definition 2. A stationary recursive competitive equilibrium after a permanent policy change is a collection of value functions $V_j(\mathbf{u})$ with associated policy functions $\{c_j(\mathbf{u}), s_j(\mathbf{u}), h'_j(\mathbf{u}), m'_j(\mathbf{u}), b'_j(\mathbf{u})\}$ for all j; prices (p_h, p_r); a quantity of total housing stock H; and a distribution of agents' states Φ_j for all j such that:

1. Given prices (p_h, p_r), $V_j(\mathbf{u})$ solves the Bellman equation (3.10) with the corresponding set of policy functions $\{c_j(\mathbf{u}), s_j(\mathbf{u}), h'_j(\mathbf{u}), m'_j(\mathbf{u}), b'_j(\mathbf{u})\}$ for all j.

2. Given p_h, the rental price per unit of housing service p_r is given by equation (3.11).

[21] We assume a perfectly elastic supply of both owner-occupied housing and rental units in the baseline steady state. This implies that supply always equals demand and thus we have market clearing.

3. The housing market clears:

$$H = \bar{H}$$
$$\text{where} \quad H = \sum_{\mathcal{J}} \Pi_j \int_U s_j(\mathbf{u}) d\Phi_j(U)$$

   and $\bar{H}$ is the housing stock from the equilibrium of the baseline economy.

4. Distributions of states Φ_j are given by the following law of motion for all $j < J$

$$\Phi_{j+1}(\mathcal{U}) = \int_U Q_j(\mathbf{u}, \mathcal{U}) d\Phi_j(U),$$

3.B Computational method and solution algorithm

The computational method and the solution method are similar to those in Karlman et al. (2020). To summarize, we use the general generalization of the endogenous grid method G^2EGM by Druedahl and Jørgensen (2017) to solve for the value and policy functions. The number of grid points for permanent earnings N_Z, cash-on-hand N_X, housing sizes N_H, bonds-over-earnings N_B, and loan-to-value N_{LTV}, are 9, 140, 30, 25, and 41, respectively. The grid points are denser at lower levels of cash-on-hand and bonds-over-earnings. Further, we simulate 300 000 households for $J = 60$ periods.

3.C Labor income process

3.C.1 Data sample

Equation (3.13) is estimated using PSID data, survey years 1970 to 1992. The variable definitions and sample restrictions are the same as in Karlman et al. (2020).

3.C.2 Estimation

In this section, we describe how the exogenous earnings process in equation (3.13) is estimated. First, we estimate the deterministic life-cycle earnings profile $g(j)$, and then we move on to the variances of the fixed-effect component σ^2_α, the permanent shock σ^2_η, and the transitory shock σ^2_ν.

To estimate the deterministic age-dependent earnings component $g(j)$, we use yearly observations in the data for ages 20 to 64. Log household earnings $\log(y_i)$ are regressed on dummies for age (not including the youngest age), marital status, family composition (number of family members besides head and, potentially, wife), and a dummy for whether the household head has a college education. Household fixed effects are controlled for by running a linear fixed-effect regression. Finally, a third-order polynomial is fitted to the predicted values of this regression, which provides us with the estimate of the deterministic life-cycle earnings profile $\hat{g}(j)$.

We follow Carroll and Samwick (1997) when we estimate the variances of the transitory (σ^2_ν) and permanent (σ^2_η) shocks. Define $\log(y^*_{ij})$ as the logarithm of household i's earnings less the household fixed component $\hat{\alpha}_i$ and the deterministic life-cycle component.

$$\begin{aligned}\log(y^*_{ij}) &\equiv \log(y_{ij}) - \hat{\alpha}_i - \hat{g}(j) \\ &= n_{ij} + \nu_{ij} \qquad\qquad \text{for } j \in [1, J_{ret}],\end{aligned}$$

where the equality follows from equation (3.13). Define r_{id} as household i's d-period difference in $\log(y^*_{ij})$,

$$\begin{aligned} r_{id} &\equiv \log(y^*_{i,j+d}) - \log(y^*_{ij}) \\ &= n_{i,j+d} + \nu_{i,j+d} - n_{ij} - \nu_{i,j} \\ &= n_{i,j+1} + n_{i,j+2} + ... + n_{i,j+d} + \nu_{i,j+d} - \nu_{i,j}. \end{aligned}$$

Since the transitory and permanent shocks are i.i.d., it follows that

$$\begin{aligned} \mathrm{Var}(r_{id}) &= \mathrm{Var}(n_{i,j+1}) + \mathrm{Var}(n_{i,j+2}) + ... + \mathrm{Var}(n_{i,j+d}) \\ &\quad + \mathrm{Var}(\nu_{i,j+d}) + \mathrm{Var}(\nu_{i,j}) \\ &= 2\,\sigma^2_\nu + d\,\sigma^2_\eta. \end{aligned}$$

These variances are estimated by running an OLS regression of $\mathrm{Var}(r_{id}) = r^2_{id}$ on d, including a constant term. The estimate of the variance of the permanent shock is given by the coefficient of d, and the estimate of the variance of the transitory shock is equal to the constant term divided by two. The estimate of the variance of the household fixed-effect component of earnings $\hat{\sigma}^2_\alpha$ is given by the residual variance in period $j = 1$,

$$\hat{\sigma}^2_\alpha = \mathrm{Var}\left(\log(y_{i1}) - \hat{g}(1)\right) - \hat{\sigma}^2_\eta - \hat{\sigma}^2_\nu.$$

3.D Additional results

3.D.1 Baseline model

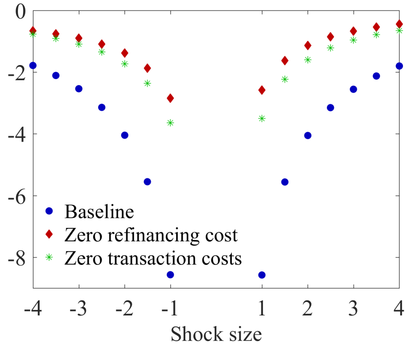
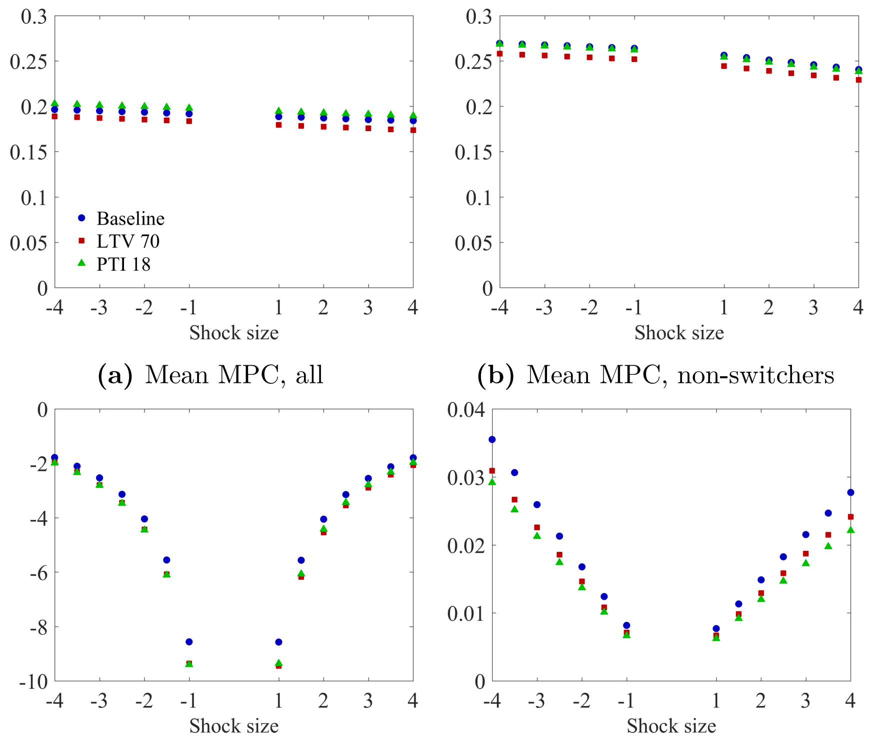


Figure 3.9: MPCs of switchers: no refinancing costs or transaction costs

Note: Mean MPC across shock size (thousands of dollars) among switchers, comparing the baseline model to a setting where there are no refinancing costs or no transaction costs for buying and selling a house. Switchers are those who change their discrete choice in response to a shock. For each new setting we solve for a new steady state, where we allow house prices to change under the assumption that the aggregate housing stock is fixed.

3.D.2 Permanent policies



(a) Mean MPC, all

(b) Mean MPC, non-switchers

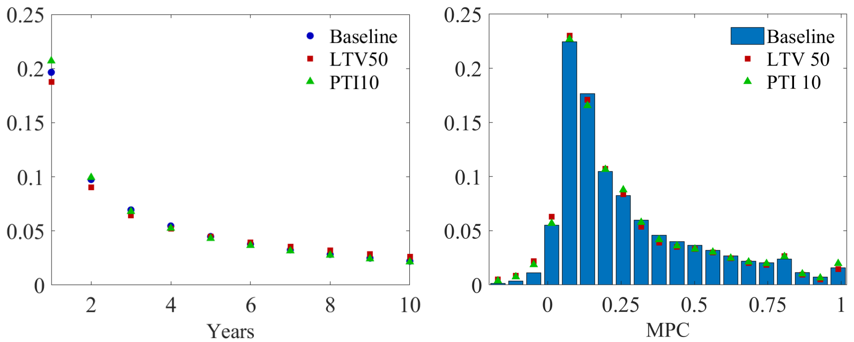
(c) Mean MPC, switchers

(d) Share who switches

Figure 3.10: Decomposing the mean MPC across shock size (thousands of dollars)
Note: Switchers are those who change their discrete choice in response to a shock.

	Baseline	Stricter LTV	Stricter PTI
Max LTV	0.90	0.50	0.90
Max PTI	0.28	0.28	0.10
House price	1	0.893	0.846
Rent	0.086	0.085	0.085
Homeownership rate	0.674	0.527	0.568
Median house-to-earnings ratio	2.259	2.022	1.803
Mean net worth age 75 over 50	1.637	1.343	1.617
Median loan-to-value ratio	0.339	0.015	0.013
Mean net worth, over mean earnings	1.381	1.458	1.367
Mean liquid savings-to-earnings	0.752	0.790	0.803

Table 3.5: Steady-state prices and moments under permanent changes in the lending policies



(a) Mean MPC over time **(b)** Distribution of MPC in $t = 1$

Figure 3.11: MPCs for different permanent policies
Note: MPCs from a wealth shock of $-4,000$ dollars in $t = 1$. In the baseline model, the LTV limit is 90 percent and the PTI constraint is 28 percent.

3.D.3 Temporary policies

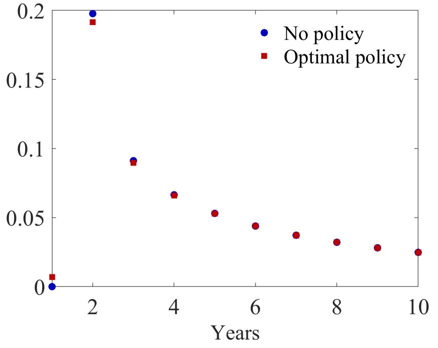
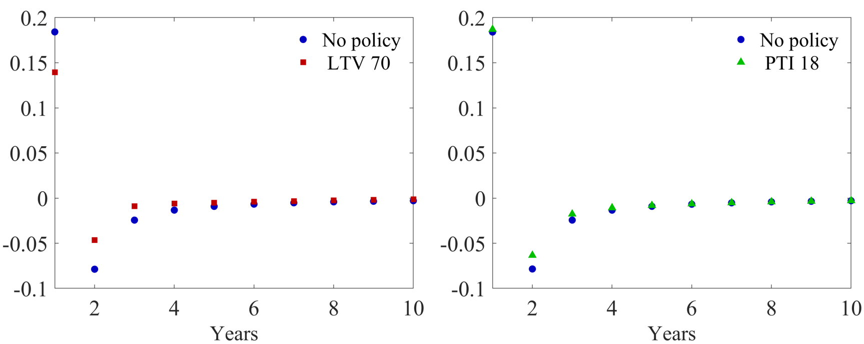


Figure 3.12: Mean MPC, for optimal temporary loan-to-value policy, over time

Note: Consumption responses under a temporary stricter LTV policy of 86 percent in $t = 1$, that is reversed in $t = 2$. Unexpected wealth shock of $-4,000$ dollars in $t = 2$. The consumption responses are normalized by $-4,000$ dollars also in $t = 1$, where there is only a change in policy and no shock has occurred. In the baseline model with no temporary policy, the LTV limit is 90 percent.



(a) Mean MPC over time **(b)** Mean MPC over time

Figure 3.13: MPCs for temporary LTV or PTI policy in boom-bust episode

Note: Consumption responses under a temporary stricter policy in $t = 1$, that is reversed in $t = 2$. Unexpected wealth shock of 4,000 dollars in $t = 1$ and $-4,000$ dollars in $t = 2$. The consumption responses are normalized by 4,000 dollars in all periods. In the baseline model with no temporary policy, the LTV limit is 90 percent and the PTI constraint is 28 percent.

Sammanfattning

Första gången jag kom i kontakt med makroekonomi under mina studier till en fil kand, var de modeller som vi använde avskalade versioner av de samhällen som de avsågs representera. Enkla regler specificerade hur stor andel av den totala inkomsten som konsumerades. Under mina masterstudier var reglerna – som verkade ha kommit från ingenstans – nu resultatet av medvetna val som gjorts av ett hushåll som maximerar sitt välbefinnande.

Övergången från en "tumregel" till ett hushåll som bryr sig om sig själv var betryggande. Ändå innebar modellerna fortfarande antaganden som det var svårt att få att överensstämma med verkligheten. Det fanns enbart ett hushåll, dvs inget du och jag. Hushållet levde i all evighet. Vidare kunde hushållet försäkra sig emot alla tänkbara osäkerheter.

Det var inte förrän jag påbörjade mina doktorandstudier i Stockholm som jag formellt introducerades till en relativt ny och viktig del av makroekonomi, vilken mildrar många av de antaganden som görs i de modeller som jag tidigare hade stött på. I den s k kvantitativa heterogena agent modellen finns det inte längre enbart ett hushåll, utan många olika hushåll vilket orden heterogen agent antyder. Hushållen kan ha ändliga liv snarare än leva för evigt och inkomsterna och tillgångarna varierar under deras livstid. Det finns en osäkerhet för hushållen när det gäller framtida inkomster och de kan inte helt försäkra sig emot dessa risker. Klyftan mellan verklighet och teori blev betydligt mindre.

Detta betyder inte att de modeller som inte har dessa ytterligare egenskaper är förlegade. I många fall är de enklare modellerna högst relevanta och kan erbjuda värdefulla insikter när de nya modellerna blir för komplicerade. Icke desto mindre, när den heterogena agent-modellen kom kunde ekonomer erbjuda nya perspektiv på gamla frågor och ställa nya frågor som våra äldre modeller inte kunde besvara. När det finns mer än ett hushåll kunde fördelningskonsekvenser och ojämlikhet bli centrala delar av analysen. Sålunda gjorde den relativt nya grenen av makroekonomi det möjligt för ämnet att inte enbart bry sig om ”storleken på kakan”, utan också hur den fördelas över befolkningen.

Den här avhandlingen består av tre fristående kapitel där såväl aggregerade effekter som fördelningseffekter spelar betydande roller. Kapitlen utforskar konsekvenserna av bostadsmarknads- och bolånemarknadspolitiken som aktivt debatteras i många länder. Den pågående debatten klargör att vissa aspekter vad gäller hushållen borde vara en del av en givande analys: vissa hushåll är unga medan andra är gamla, vissa hushåll hyr sina hem medan andra äger dem och medan vissa hushåll är fattiga så är andra rika. För att fånga komplexiteten i denna politik, använder jag modeller som bygger på de som jag först fick kunskap om under mina doktorandstudier.

Innan jag går vidare till de fullständiga kapitlen följer här en något mindre teknisk översikt av kapitlen.

I kapitel 1, Kostsamma reformer av dåliga subventioner — fallet med ränteavdraget (Costly reversals of bad policies: the case of the mortgage interest deduction), tillsammans med Markus Karlman och Karin Kinnerud, studerar vi hur hushåll i USA påverkas om man tar bort ränteavdraget för bolån och huruvida detta är en bra idé.

Ränteavdraget är en skattesubvention som har fått en hel del uppmärksamhet i de politiska diskussionerna USA. Subventionen gör det möjligt för husägare att dra av räntebetalningar på hypotekslån från sina skattepliktiga inkomster. Eftersom avdragsrätten för hypotekslån kan minska husägarnas skatter, minskar det i praktiken kostnaden för bolån och därmed kostnaden för att äga en bostad. Sålunda påverkas många hushåll av ränteavdraget, inte bara i sina beslut att äga eller hyra en bostad, men också när det gäller hur stort hus man väljer att köpa. Subventionen kritiseras emellertid ofta för att främst främja höginkomsttagare på andra skattebetalares bekostnad. Ungefär hälften av avdragen går till hushåll i de övre 20 procenten av inkomstfördelningen, medan hushållen i de lägsta 20 procenten knappt gör några ränteavdrag.

För att skapa en bättre förståelse för vem som skulle dra nytta av och vem som skulle förlora på att avskaffa avdragsrätten för räntebetalningar på hypotekslån, utför vi experiment i en modell som är utformad för att representera det amerikanska samhället. Vi börjar med att analysera de långsiktiga välfärdseffekterna, dvs vi jämför om hushållen skulle föredra att födas in i ett samhälle med eller utan avdragsrätt för hypotekslån. Våra resultat visar att en stor majoritet av hushållen skulle föredra ett samhälle utan ränteavdrag. I ett samhälle utan skattesubventionen väljer hushåll med högre inkomster att bo i mindre egenägda bostäder. Detta leder till lägre priser för ägda och hyrda bostäder, vilket är speciellt gynnsamt för hushåll med låga inkomster. Vidare, när regeringen inte längre subventionerar räntebetalningar på hypotekslån kan andra skatter sänkas. Medan enbart vissa hushåll drar nytta av avdragsrätten för hypotekslån gynnas alla hushåll av en lägre inkomstskatt.

Givet de stora välfärdsvinsterna av att ta bort hypotekslånesubventionen på lång sikt, fortsätter vi med att undersöka hur nuvarande hushåll skulle påverkas av ett borttagande. Effekterna av ett avlägsnande är väldigt annorlunda för dessa hushåll. I dag har många hushåll tagit långsiktiga bostads-och bolånebeslut baserat på antagandet att de kan göra ränteavdrag. När subventionen oväntat tas bort faller bostadspriserna kraftigt, vilket drabbar de existerande husägarna avsevärt. Vidare inser många hushåll att de har för stora hus och bolån, när de inte längre kan dra av sina räntebetalningar. De som hyr, å andra sidan, vinner på reformen då de drar nytta av fallet i bostadspriserna.

Våra resultat visar att hushållen i genomsnitt får det sämre om ränteavdraget omedelbart tas bort i sin helhet och en majoritet av hushållen är negativt inställda till en sådan reform. 70 procent av hushållen i USA äger sina hem och de positiva effekter som hyresgästerna får överstiger inte de negativa effekterna för husägarna. Vi visar också att dessa resultat även håller om avskaffandet av ränteavdraget tas bort gradvis eller om det tillkännages i förväg. Våra resultat tyder på att ännu färre hushåll är positiva till ett avskaffande under dessa alternativa implementeringar. Trots att ett mer gradvist borttagande mildrar förlusterna för dem som drabbas värst av reformen, minskar det också vinsterna. Därmed visar våra resultat att kostnaderna för att reformera en dålig politik kan vara avsevärda – även i en sådan utsträckning att det kanske inte är värt det.

I kapitel 2, Optimal fastighetsbeskattning (Optimal property taxation), analyserar jag hur mycket vi bör beskatta bostadsfastigheter.

I de flesta länder är bostadsfastigheter antingen undantagna från skatter eller är ganska milt beskattade. Däremot är skatten på inkomster från andra investeringar, så som avkastningen på sparkonton, ofta hög. Många ekonomer hävdar att detta skattesystem har olyckliga konsekvenser för hushållen och samhället. De hävdar att en låg skatt på bostäder, relativt annat kapital, gör att hushållen sparar för mycket i bostäder på bekostnad av kapital som skulle kunna användas i företagens produktion. Intuitivt är kapital som inte är investerat i bostäder inte lika lukrativt när hushållen inte får behålla den totala avkastningen på de investeringarna. Följaktligen har företagen färre maskiner och mindre utrustning per arbetstagare vilket minskar arbetskraftsproduktiviteten. Företagen är därför mindre benägna att betala höga löner. Om företagen hade mer kapital skulle hushållens inkomster från arbete kunna öka.

Emellertid finns det också nackdelar med att höja fastighetsskatten för att sänka skatten på kapitalinkomster. Högre fastighetsskatt leder till ett dyrare boende för många hushåll. Sålunda kan det bli så att hushållen inte har råd att bo i det hem de annars skulle välja.

För att kvantifiera avvägningen mellan en skatt på bostäder gentemot en skatt på kapitalinkomster, använder jag en modell av det amerikanska samhället. Modellen inkluderar många av de viktiga aspekterna vad gäller problemet i fråga: hushåll kan investera i bostäder eller finansiella investeringar; ett företag behöver kapital och arbetskraft för att producera varor och tjänster, kapitalinkomster och bostäder beskattas enligt olika skattesatser; och regeringen kan sänka skatten på kapitalinkomster om den höjer skatten på bostadsfastigheter.

Resultaten av min analys av de långsiktiga effekterna av fastighetsbeskattning stödjer generellt det traditionella synsätt som många ekonomer har: Fastighetskatten bör öka avsevärt. Den optimala fastighetsskatten är ca fem gånger högre än dagens nivå på en procent. Detta gör det möjligt för regeringen att sänka kapitalinkomstskatten från nuvarande 36 procent till nära noll procent. Detta leder till att nästan alla hushåll får det bättre. Hushåll som har relativt låg produktivitet drar störst nytta av den resulterande högre lönen.

Betyder detta att beslutsfattarna i USA borde ändra dagens skattesatser? Inte nödvändigtvis. De genomsnittliga välfärdseffekterna hos nuvarande generationer är i själva verket störst när fastighetskatten ligger nära dagens nivå på en procent. Medan unga hushåll och de som hyr sin bostad i genomsnitt skulle få det bättre med en högre nivå på fastighetsskatten skulle andra hushåll få det betydligt sämre. Framför allt vill pensionärer och ägare till mindre bostäder generellt sänka den nuvarande nivån på fastighetsskatten.

Generellt ger skillnaden i de optimala skatterna på kort och lång sikt oss en logisk grund för att förstå hur fastighetsskatten kan gynna somliga (t.ex. framtida generationer) men inte andra (t.ex. pensionärer). En huvudslutsats av mitt arbete är att policyrekommendationer vad gäller fastighetsbeskattning bör ta de kortsiktiga övervägandena på allvar.

I kapitel 3, Utlåningsregler för bolån: implikationer för fluktuationer i konsumtion (Mortgage lending standards: implications for consumption dynamics), även detta samförfattat med Markus Karlman och Karin Kinnerud, studerar vi huruvida mer strikta regler för bolån kan minska fallet i konsumtionen under ekonomiska nedgångar. Mer specifikt studerar vi i vilken utsträckning bolåneregler påverkar i vilken omfattning hushåll ändrar sin konsumtion, när de upplever en tillfällig minskning av sina tillgångar.

Myndigheter i många länder har infört striktare krav för bolån under senare år. Denna utveckling är delvis motiverad av erfarenheterna från den stora recessionen, där områden med en högre tillväxt i skuldsättningen via bolån innan krisen upplevde en kraftigare minskning av konsumtionen när krisen slog till. Med de nya bolånekraven hoppas man att framtida nedgångar blir mindre allvarliga. Det är emellertid inte uppenbart att de striktare utlåningskraven är framgångsrika när det gäller att stabilisera ekonomin. Ett sätt på vilket hushållen kan undvika en tillfällig minskning av konsumtionen är just genom att öka sin skuldsättning. Genom att begränsa möjligheterna att låna har hushållen färre möjligheter att mildra konsekvenserna av en minskning av sina finansiella resurser. Därmed kan konsumtionsresponsen till och med vara starkare när striktare regleringar är på plats.

I den här artikeln använder vi en modell för att utföra experiment där belåningsgradskravet (med andra ord kontantinsatskravet) och skuldkvotskravet görs mer strikta. Belåningsgradskravet specificerar det maximala bolånet ett hushåll kan erhålla, som en andel av bostadens värde. Skuldkvotskravet begränsar storleken på bolånet i förhållande till inkomsten. I våra experiment studerar vi först en permanent förskjutning av belåningsgradskravet från det nuvarande värdet på 0,90 till 0,70, eller skuldkvotskravet från dess nuvarande värde på 0,28 till 0,18 (det nuvarande värdet specificerar att inte mer än 28 procent av den årliga inkomsten får läggas på bostadsrelaterade kostnader, dessa kostnader inkluderar räntebetalningar och amortering av bolån). Vi utforskar sedan en temporär implementering av de striktare kraven, under ett år som föregår en ekonomisk nedgång.

Vårt första resultat är att permanent striktare bolåneregleringar enbart marginellt påverkar hur mycket hushållen minskar sin konsumtion, vid en ekonomisk nedgång. De striktare kraven påverkar emellertid hushållen på flera viktiga sätt. Färre hushåll äger sina bostäder, de har lägre skuldsättning och sparar i genomsnitt aningen mer. Av yttersta vikt är dock att dessa beteendeförändringar är sådana att hushållens totala förmåga att hantera ekonomiska nedgångar i princip förblir oförändrad. Det här resultatet håller även för större förändringar av kraven för utlåning.

Vårt andra resultat är att tillfälligt striktare krav för bolån kan framgångsrikt begränsa konsumtionsminskningen under en ekonomisk nedgång. Temporärt striktare krav för bolån förhindrar vissa människor från att köpa hus och leder till att vissa hushåll tar ut mindre bolån. Till följd av detta har hushållen mer disponibla besparingar när den ekonomiska nedgången inträffar än de skulle ha haft utan de striktare regleringarna. Därmed är de bättre förberedda att hantera en minskning av sina tillgångar. Det är emellertid enbart under specifika omständigheter som temporärt striktare bolånekrav leder till att hushållen får det bättre. För det första måste den ekonomiska nedgången vara stor. För det andra behöver en beslutsfattare ha en informationsfördel genom att denne kan förutse nedgången, medan hushållen inte kan göra det.

En mer generell slutsats i den här avhandlingen är att moderna makroekonomiska modeller inte bara erbjuder en rikare och mer realistisk modellmiljö, men de kan också användas för att försöka förstå politisk beslut. Det är trots allt sällan som policyförändringar genomförs enbart baserat på effektivitetsvinster, vilket är fokus i ekonomiska modeller med enbart ett hushåll. Därmed kan en policy som framstår som dålig i en modellmiljö med endast en typ av hushåll fortfarande användas i praktiken då tillräckligt många människor gynnas av den. Den här avhandlingen gör inte anspråk på att ge en fullständig beskrivning av den politiska beslutsprocessen, men jag hoppas att den berikar vår förståelse kring varför viss politik och policy väljs.

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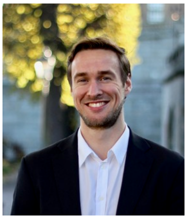

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