

Essays on Housing

tax treatment, prices, and macroeconomic implications

Markus Karlman



Essays on Housing

tax treatment, prices, and macroeconomic implications

Markus Karlman

Academic dissertation for the Degree of Doctor of Philosophy in Economics at Stockholm University to be publicly defended on Friday 11 September 2020 at 09.00 in hörsal 5, hus B, Universitetsvägen 10 B.

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.

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.

The great house price divergence: a quantitative investigation of house price fundamentals

What explains the widening gap in house prices between U.S. metropolitan areas? In this paper, I build a two-region Rosen-Roback model with heterogeneous households, mortgage borrowing constraints, and housing markets to answer this question. I find that changes in regional productivity and the real interest rate explain 86% of the observed increase in dispersion of prices across metropolitan areas and 66% of the increase in the national house price index since 1995. Endogenous migration and location-varying land rents are key for these findings. When decomposing the results, both wages and the real rate contribute substantially to both the change in the level and dispersion of house prices. Turning to dynamics, prices are quick to adjust to changes in house price fundamentals, whereas migration is slow. This rapid change in prices leads to significant wealth and welfare gains among homeowners in expensive locations.

Keywords: *macroeconomics, housing, house prices, mortgage interest deduction, marginal propensity to consume, welfare, heterogeneous agents.*

Stockholm 2020

<http://urn.kb.se/resolve?urn=urn:nbn:se:su:diva-182467>

ISBN 978-91-7911-202-8

ISBN 978-91-7911-203-5

ISSN 0346-6892



Stockholm
University

Department of Economics

Stockholm University, 106 91 Stockholm

ESSAYS ON HOUSING

Markus Karlman



Essays on Housing

tax treatment, prices, and macroeconomic implications

Markus Karlman

©Markus Karlman, Stockholm University 2020

ISBN print 978-91-7911-202-8

ISBN PDF 978-91-7911-203-5

ISSN 0346-6892

Cover photo: The old house (by Uno Karlman)

Printed in Sweden by Universitetsservice US-AB, Stockholm 2020

To my wife and my dog

Acknowledgements

Should I get a PhD in economics? I guess that is a question that many students ask themselves after studying economics for a couple of years. I did not. I often say that I would not stand a chance of getting a proper job outside of academia, so becoming a graduate student was my only option. That is probably a bit of an exaggeration. The most important reason why I chose this path in life is that I love being a student. The best feeling I know is going home from the university in the evening, knowing more about the world than I did when I left home in the morning. As an undergraduate, learning comes mostly from reading books and attending lectures. As a graduate student, you learn predominately from the people around you. For that reason, I would like to acknowledge some of the people who I have learned from over the past few years, and some people who have been important to me for a long time.

I would like to start by acknowledging my fellow graduate students, who are the ones who have had the biggest impact on my daily life. One of my big regrets is not getting to know many of them better. But on the other hand, when you spend your days being frustrated about the lack of progress on your job market paper, this is easier said than done. Especially for an introvert like me. Luckily, the world of economic research is surprisingly small. I am sure that our paths will cross in the future, one way or another.

Two people I did get to know quite well are Karin Kinnerud and Kasper Kragh-Sørensen. Two of the chapters in this thesis are co-authored with them, and I must say that I am quite proud of what we accomplished. I feel a sense of pride when I look at chapter 1, the first paper that we wrote together. Not just because of the end result, but also because of how much I learned along the way. Both Karin and Kasper possess skills that I lack, and have a different way of looking

at things than I do. Working closely with them has made me a better economist, a more disciplined student, a more critical thinker, and a more humble person.

Regarding the first two chapters, they wouldn't have been nearly as good if it wasn't for Per Krusell. I have benefited a lot from Per's vast knowledge and experience. If it wasn't for that long meeting with Per a few months ago, the second chapter of this thesis may very well have been little more than an incoherent collection of graphs and figures. Per has also been instrumental in helping us navigate through the publication process, which eventually resulted in getting the first chapter of this thesis (conditionally) accepted at a reputable journal. In addition, I want to acknowledge Per's role in making the macro group at the IIES more than just a seminar series. I am especially grateful for him inviting all of the job market candidates to his summer house last year. Those were the best days of 2019, and really lifted my spirit during the most difficult time of my life.

I would also like to thank John Hassler. My admiration for John as an economist goes all the way back to 2009, when I took the first-year course in macroeconomics. This course was taught by John, and I quickly realized that this was the subject I would devote my studies to. John taught macro in a clear and coherent way, always connecting every new model and concept to the real world. This emphasis on connecting model to reality, and never losing sight of the big picture, is not just something that characterizes John's teaching, but also the comments and advice that he has given me.

However, the most important faculty member at the IIES for me has been Kurt Mitman. Without Kurt's help, I would have been completely lost on the job market. Kurt was the person I turned to for help during the process of writing my job market paper. As the market drew near, he helped me prepare for the interviews, advised me on how to pitch my paper, and even told me what color tie to wear ("red or blue"). Kurt answered all of my questions, no matter

how stupid they were, and would often ask me how I was doing. In my time of need, I felt like he cared, and for that I am very grateful. Chapter 3 of this thesis is not a paper I am particularly proud of, but without Kurt's advice and encouragement it wouldn't even exist, and consequently there would be no thesis to defend.

Outside of the institute, I owe a huge thanks to my family. As a child, my parents always encouraged me to learn new things, and repeatedly pointed out the importance of acquiring a good education. My mother in particular has had a huge influence on me. Despite never setting foot at a university, she has probably read more books about history and politics than the average social science graduate ever will. I think it is fair to say that she is the reason I became so interested in social science in the first place. I also want to thank my brother, who is the true intellectual of the family. I have always been inspired by his vast knowledge and his ability to look at things from many different perspectives.

Finally, I want to thank my wife Linda-Marie. Even though we have been together for 11 years, she never ceases to amaze me. I realize that I can't have been easy to live with, especially during the first and the last year of the PhD program. Nevertheless, she has supported me throughout and never held me back from pursuing my dream of eventually getting a PhD. Whenever I doubted myself during the job market year, she always reminded me that I would not be happy working with anything else. "You love what you do, and you have been talking about getting this PhD since we met", is what she would say. And, as usually is the case, she was right.

Markus Karlman
August 2020
Stockholm

Contents

Introduction	i
1 Costly reversals of bad policies: the case of the mortgage interest deduction	1
1.1 Introduction	2
1.2 Model	7
1.3 The MID and the benefit of owning	20
1.4 Calibration	23
1.5 Results	34
1.6 Concluding remarks	53
References	55
1.A Equilibrium definitions	59
1.B Computational method	63
1.C Solution algorithm	66
1.D Labor income process	70
1.E A grandfather policy	74
1.F Welfare effects: equilibrium assumptions	78
1.G Tax Cuts and Jobs Act: long-run results	79
2 Mortgage lending standards: implications for consumption dynamics	81
2.1 Introduction	82

2.2	Model	87
2.3	Calibration	94
2.4	Results	103
2.5	Concluding remarks	120
	References	122
2.A	Definitions of stationary equilibrium	125
2.B	Computational method and solution algorithm	127
2.C	Labor income process	128
2.D	Additional results	130
3	The great house price divergence: a quantitative investigation of house price fundamentals	135
3.1	Introduction	136
3.2	Related literature	141
3.3	A simple model	144
3.4	Model	151
3.5	Calibration	165
3.6	Results	171
3.7	Concluding remarks	185
	References	188
3.A	Calibration details	192
3.B	Equilibrium definitions	195
3.C	Solution algorithm	199
3.D	House characteristics across locations	203
	Sammanfattning (Swedish summary)	205

Introduction

This thesis consists of three self-contained chapters, all studying questions related to the housing market. Methodologically, they share many features, using heterogeneous-agent models with housing and mortgage markets to answer the different questions. The chapters are organized in chronological order, with the oldest paper appearing first.

In the first chapter, **Costly reversals of bad policies: the case of the mortgage interest deduction**, jointly written with Karin Kinnerud and Kasper Kragh-Sørensen, 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. The subsidy is often criticized, however, 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 the 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, **Mortgage lending standards: implications for consumption dynamics**, also coauthored with Karin Kinnerud and Kasper Kragh-Sørensen, 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. We then 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 hinders 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.

In chapter 3, **The great house price divergence: a quantitative investigation of house price fundamentals**, I study the evolution of house prices in the U.S. over the last 25 years, at both the national and at the city level.

It is well known that the U.S., like most other developed countries, has seen an increase in the national house price level over this time period. In fact, the period since 1995 stands out as having the most rapid growth in house prices in modern history. What is perhaps less well known is that there is significant variation in the way house prices have evolved at the regional level. By comparing the evolution of prices across U.S. cities, I document something that I call "house price

divergence”. Cities that were cheap in the 1990’s have typically not seen much of an increase in house prices, whereas places that were already expensive 25 years ago have often seen prices soar. The aim of the paper is to explain these two facts. Why has the U.S. seen a record increase in house prices at the national level? And why is this driven by places that were already expensive to begin with?

To answer these questions, I specify a model and use it to put a number on the importance of wages, the interest rate, and housing supply, for the evolution of house prices between 1995 and 2018. In addition to having a detailed specification of the housing market, the model has two regions, and allows households to move between them at their own discretion. This feature of the model is key for understanding price divergence. Since households choose to live in their preferred location, the price difference between the two regions needs to be such that some households are indifferent about where to live. In other words, the relative price acts as a compensating differential.

The main finding of the paper is that both changes in wages and the real interest rate are important for explaining the evolution of house prices. Together, these two forces explain around 86% of the divergence of prices, and 66% of the increase in the national house price level. I therefore conclude that the dramatic changes in house prices over the last 25 years are fairly well explained by fundamentals.

A second finding is that house price divergence is mainly a result of households’ desire to migrate. If households are not allowed to move, it no longer follows that the relative price between the two regions has to be such that the marginal household is indifferent between them. Instead, housing demand, and therefore the house price, is only determined by the housing demand among those who already live in the region to begin with. When I remove the migration choice from the model, I find that the model barely generates any house price divergence at all. I therefore conclude that the uneven increase

in wages across regions and the secular decline in the real interest rate mainly leads to a desire among households to move between regions. And it is mainly through this migration channel that house price fundamentals lead to such different paths of house prices across locations.

Chapter 1

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

*This paper has been jointly written with Karin Kinnerud and Kasper Kragh-Sørensen. 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

¹Total 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.

²See, 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.

³In 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

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

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),

⁴The 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

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

where v 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

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

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

$$m' \leq (1 - \theta)p_h h'. \quad (1.4)$$

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,

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

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

⁵The 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).

⁶Mortgage 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

⁷For 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.

⁸The 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

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

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

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

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 $S = \{\underline{s}, s_2, s_3, \dots, \bar{s}\}$.

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

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

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{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

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

⁹A 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).

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

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

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

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

with the corresponding set of policy functions

$$\left\{ c_j(z, x, h, m), s_j(z, x, h, m), h'_j(z, x, h, m), m'_j(z, x, h, m), b'_j(z, x, h, m) \right\}.$$

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

$$\pi_f^{Rent} = (1 - \tau^c) \left(p_r h_f - \frac{1}{1 + \tilde{r}} \left[\delta^r + \tau^h p'_h + \Delta p'_h \right] h_f \right).$$

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

¹⁰The 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

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

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,

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

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

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

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

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

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

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

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

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 $t \in \{1, \dots, T\}$, 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

$$NB^{Own} = UC^{Rent} - UC^{Own}, \quad (1.14)$$

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 $ID' = \tau^h p_h' h' + \tau^m rm'$, 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

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

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 ($\tau^m=1$).

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

¹¹See 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

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

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

¹²For 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

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

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

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

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{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
v	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{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 v 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

¹³In 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.

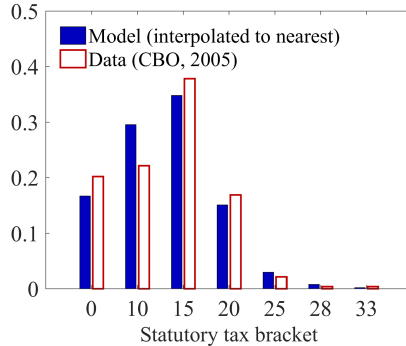


Figure 1.1: Fractions of taxpayers facing different marginal tax rates

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

¹⁴The 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.

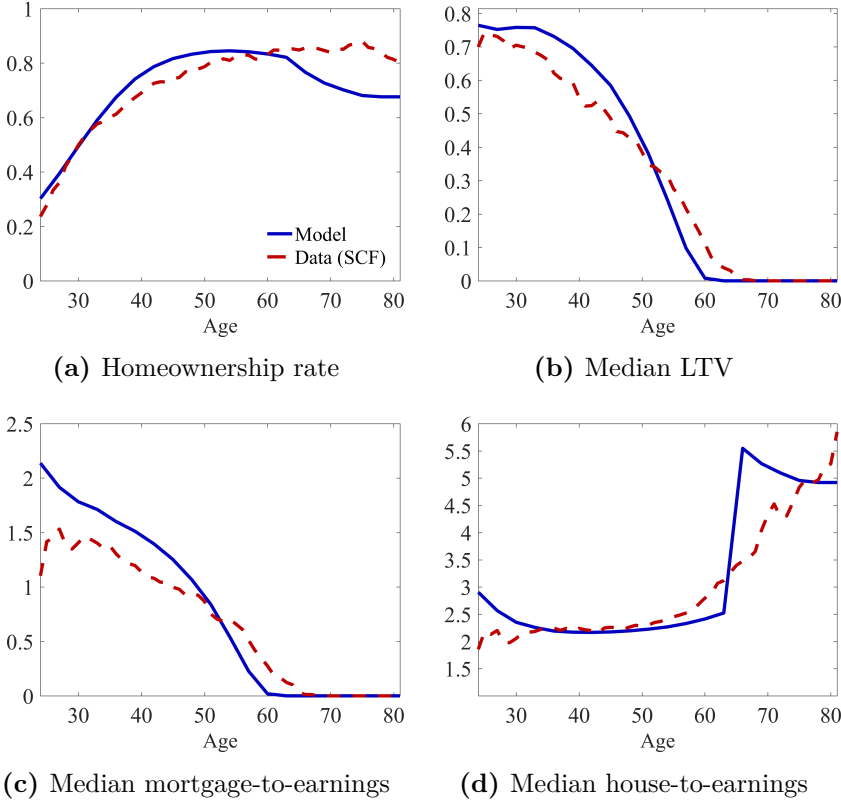


Figure 1.2: Comparison of model versus data: non-targeted profiles

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.

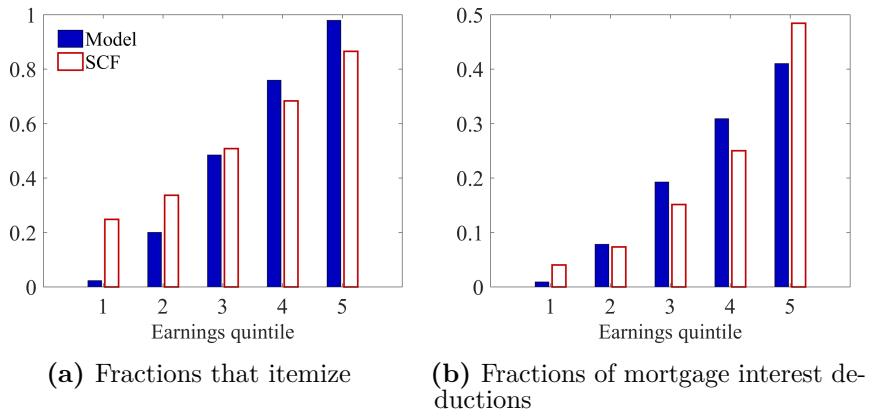


Figure 1.3: Itemizers and MID claims in the initial steady state, across earnings quintiles

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

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

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.

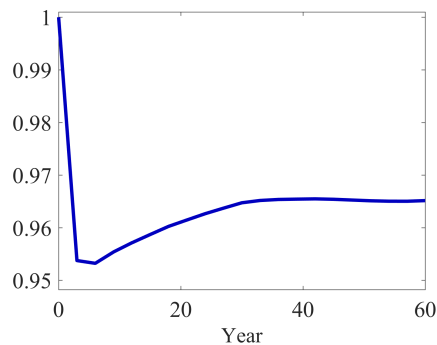


Figure 1.4: House price dynamics from an immediate removal of the MID

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.

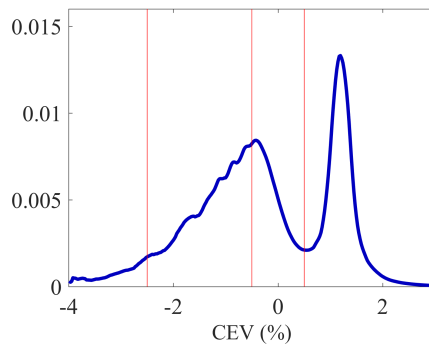


Figure 1.5: The distribution of welfare effects under the immediate removal policy

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 $\{\tau_t^m\}_{t=1}^{t=\infty} = \{1, 0.8, 0.6, 0.4, 0.2, 0, 0, \dots\}$. 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., $\{\tau_t^m\}_{t=1}^{t=\infty} = \{1, 1, 1, 1, 1, 0, 0, \dots\}$. 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.

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,

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

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.

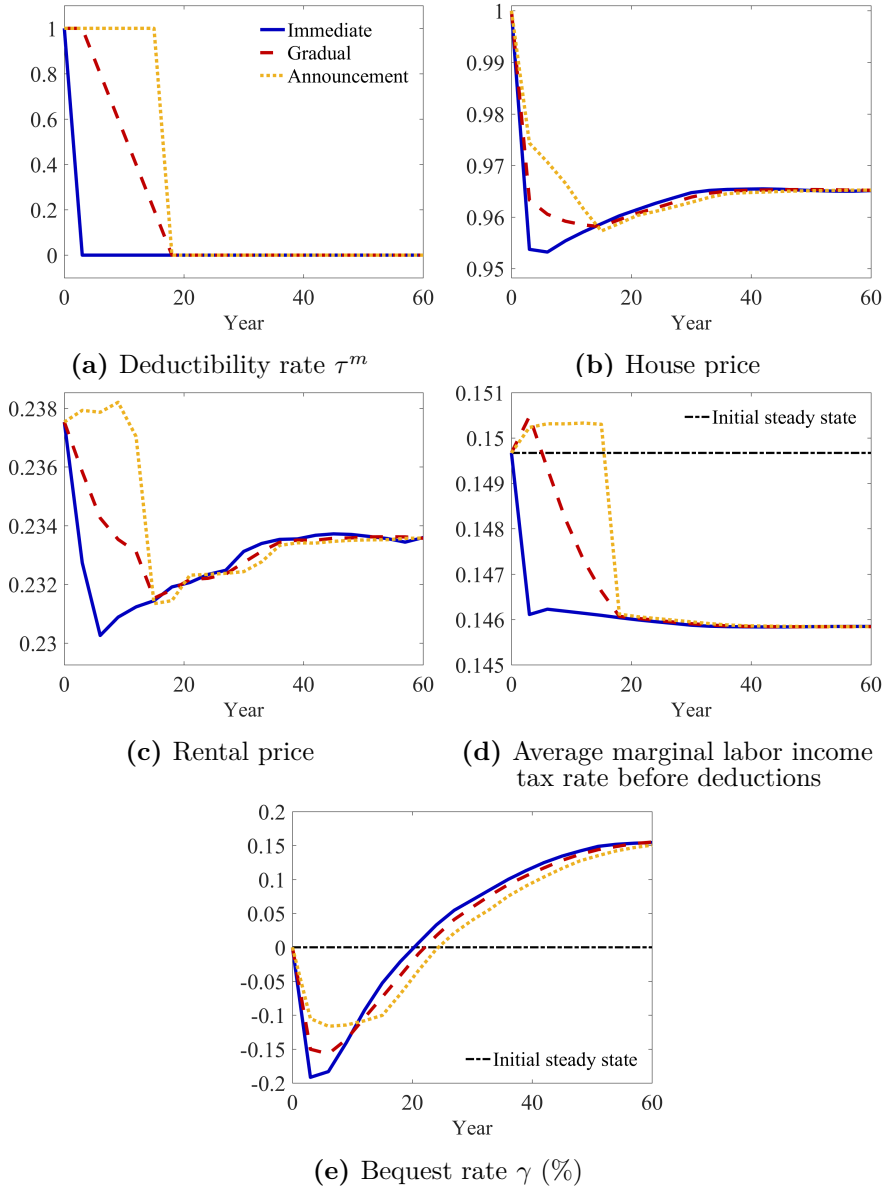


Figure 1.6: Short-run dynamics from removing the MID, across policies

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.

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

¹⁶Specifically, 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.

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 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.

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

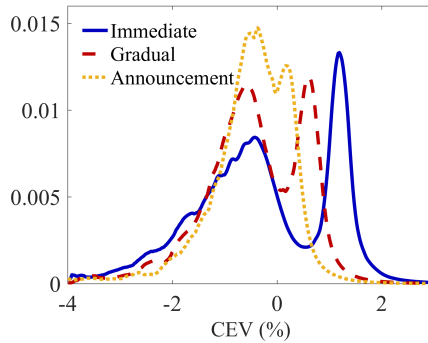


Figure 1.7: Distributions of short-run welfare effects, across policies

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.

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 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

¹⁸There 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

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

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.

¹⁹Under 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).

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.

	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.

References

- Bell, F. C. and M. L. Miller (2005, August). Life tables for the United States Social Security Area 1900-2100. Actuarial study No. 120, Social Security Administration.
- Boar, C., D. Gorea, and V. Midrigan (2020). Liquidity constraints in the U.S. housing market. *Working Paper*.
- Carroll, C. D. (2006). The method of endogenous gridpoints for solving dynamic stochastic optimization problems. *Economics Letters* 91 (3), 312–320.
- Carroll, C. D. and A. A. Samwick (1997). The nature of precautionary wealth. *Journal of Monetary Economics* 40 (1), 41–71.
- Chambers, M., C. Garriga, and D. E. Schlagenhauf (2009). Housing policy and the progressivity of income taxation. *Journal of Monetary Economics* 56 (8), 1116–1134.
- Cho, S.-W. and J. Francis (2011). Tax treatment of owner occupied housing and wealth inequality. *Journal of Macroeconomics* 33, 42–60.
- Cocco, J. F., F. J. Gomes, and P. J. Maenhout (2005). Consumption and portfolio choice over the life cycle. *Review of Financial Studies* 18 (2), 491–533.
- Conesa, J. C. and D. Krueger (1999). Social security reform with heterogeneous agents. *Review of Economic Dynamics* 2 (4), 757–795.
- De Nardi, M. (2004). Wealth inequality and intergenerational links. *The Review of Economic Studies* 71 (3), 743–768.
- Desmond, M. (2017). How homeownership became the engine of American inequality. *The New York Times Magazine*. May 9th, 2017.

- Díaz, A. and M. J. Luengo-Prado (2008). On the user cost and homeownership. *Review of Economic Dynamics* 11(3), 584–613.
- Druehl, J. and T. H. Jørgensen (2017). A general endogenous grid method for multi-dimensional models with non-convexities and constraints. *Journal of Economic Dynamics and Control* 74, 87–107.
- Floetotto, M., M. Kirker, and J. Stroebe (2016). Government intervention in the housing market: who wins, who loses? *Journal of Monetary Economics* 80, 106–123.
- Gale, W. G., H. Gelfond, A. Krupkin, M. J. Mazur, and E. J. Toder (2019). Effects of the Tax Cuts and Jobs Act: a preliminary analysis. *National Tax Journal* 71(4), 589–612.
- Gervais, M. (2002). Housing taxation and capital accumulation. *Journal of Monetary Economics* 49(7), 1461–1489.
- Greenwald, D. (2018). The mortgage credit channel of macroeconomic transmission. *Working Paper*.
- Gruber, J. W. and R. F. Martin (2003). Precautionary savings and the wealth distribution with illiquid durables. *International Finance Discussion Papers* 773.
- Güvenen, F. (2009). An empirical investigation of labor income processes. *Review of Economic Dynamics* 12(1), 58–79.
- Harding, J. P., S. S. Rosenthal, and C. Sirmans (2007). Depreciation of housing capital, maintenance, and house price inflation: estimates from a repeat sales model. *Journal of Urban Economics* 61(2), 193–217.
- Harris, E. (2005, November). Effective marginal tax rates on labor income. A CBO paper, Congressional Budget Office.

- Heathcote, J., K. Storesletten, and G. L. Violante (2017). Optimal tax progressivity: an analytical framework. *Quarterly Journal of Economics* 132(4), 1693–1754.
- Henderson, J. V. and Y. M. Ioannides (1983). A model of housing tenure choice. *American Economic Review* 73(1), 98–113.
- JCT (2017, January). Estimates of federal tax expenditures for fiscal years 2016-2020. Joint committee print, Joint Committee on Taxation.
- Kaplan, G., K. Mitman, and G. Violante (2020). The housing boom and bust: model meets evidence. *Journal of Political Economy*, Forthcoming.
- Kaplan, G. and G. Violante (2014). A model of the consumption response to fiscal stimulus payments. *Econometrica* 82(4), 1199–1239.
- Lowry, S. (2014, August). Itemized tax deductions for individuals: data analysis. Crs report for congress, Congressional Research Service.
- Piazzesi, M. and M. Schneider (2016). Housing and macroeconomics. *Handbook of Macroeconomics* 2, 1547–1640.
- Sommer, K. and P. Sullivan (2018). Implications of US tax policy for house prices, rents, and homeownership. *American Economic Review* 108(2), 241–74.
- Storesletten, K., C. I. Telmer, and A. Yaron (2004). Consumption and risk sharing over the life cycle. *Journal of Monetary Economics* 51(3), 609–633.

- Tauchen, G. (1986). Finite state Markov-chain approximations to univariate and vector autoregressions. *Economics Letters* 20(2), 177–181.
- The Tax Foundation (2013). U.S. federal individual income tax rates history, 1862-2013 (nominal and inflation-adjusted brackets).
- Ventry, D. J. (2010). The accidental deduction: a history and critique of the tax subsidy for mortgage interest. *Law and Contemporary Problems* 73(1), 233–284.

1.A Equilibrium definitions

1.A.1 Stationary equilibria

Households are heterogeneous with respect to age $j \in \mathcal{J} \equiv \{1, 2, \dots, J\}$, permanent earnings $z \in \mathcal{Z} \equiv \mathbb{R}_{++}$, mortgage $m \in \mathcal{M} \equiv \mathbb{R}_+$, owner-occupied housing $h \in \mathcal{H} \equiv \{0, \underline{h}, \dots, \bar{h} = \bar{s}\}$, 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 $\mathcal{B}(\mathcal{U}) \equiv \mathbf{B}(\mathbb{R}_{++}) \times \mathbf{B}(\mathbb{R}_+) \times P(\mathcal{H}) \times \mathbf{B}(\mathbb{R}_{++})$. Further, let \mathbb{M} be the set of all finite measures over the measurable space $(\mathcal{U}, \mathcal{B}(\mathcal{U}))$. Then $\Phi_j(U) \in \mathbb{M}$ is a probability measure defined on subsets $U \in \mathcal{B}(\mathcal{U})$ 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 $\{c_j(\mathbf{u}), s_j(\mathbf{u}), h'_j(\mathbf{u}), m'_j(\mathbf{u}), b'_j(\mathbf{u})\}$ 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 services²⁰

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

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 $Q_j : \mathcal{U} \times \mathcal{B}(\mathcal{U}) \rightarrow [0, 1]$ 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:

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 .

²⁰We 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.

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 $U_t \in \mathcal{B}(\mathcal{U})$ 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:

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

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

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 $Q_{tr,jt} : \mathcal{U} \times \mathcal{B}(\mathcal{U}) \rightarrow [0, 1]$ is a transition function that defines the probability that a household of age j at time t transits from its current state \mathbf{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 $Z_j \equiv \{z_{j,1}, \dots, z_{j,N_Z}\}$ and cash-on-hand $X \equiv \{x_1, \dots, x_{N_X}\}$.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 take into account the concavity of the value function by letting the

²¹We 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.

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 $H \equiv \{0, h_1, \dots, h_{N_H}\}$ 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 G²EGM 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 for bonds over earnings $B_y \equiv \{b_{y,1} = 0, b_{y,2} = \epsilon, b_{y,3}, \dots, b_{y,N_B}\}$ where

²²Note 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 .

$N_B = 25$ and the grid points are denser at lower levels of bonds over earnings. The finite grid for loan-to-value is $LTV \equiv \{ltv_1 = 0, ltv_2 = \epsilon, \dots, (1 - \theta - \epsilon), (1 - \theta), (1 - \theta + \epsilon), \dots, ltv_{N_{LTV}}\}$ 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 $\gamma_t = \gamma_{new} \forall t \in \mathcal{T} \equiv \{1, \dots, T\}$:

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

²³We 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 $age \in \{20, 21, \dots, 64\}$. 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

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

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

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

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

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

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

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

We estimate these variances by running an OLS regression of $\text{Var}(r_{id}) = r_{id}^2$ 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_α^2 is the residual variance in period $j = 1$ as follows

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

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 equa-

tion (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.

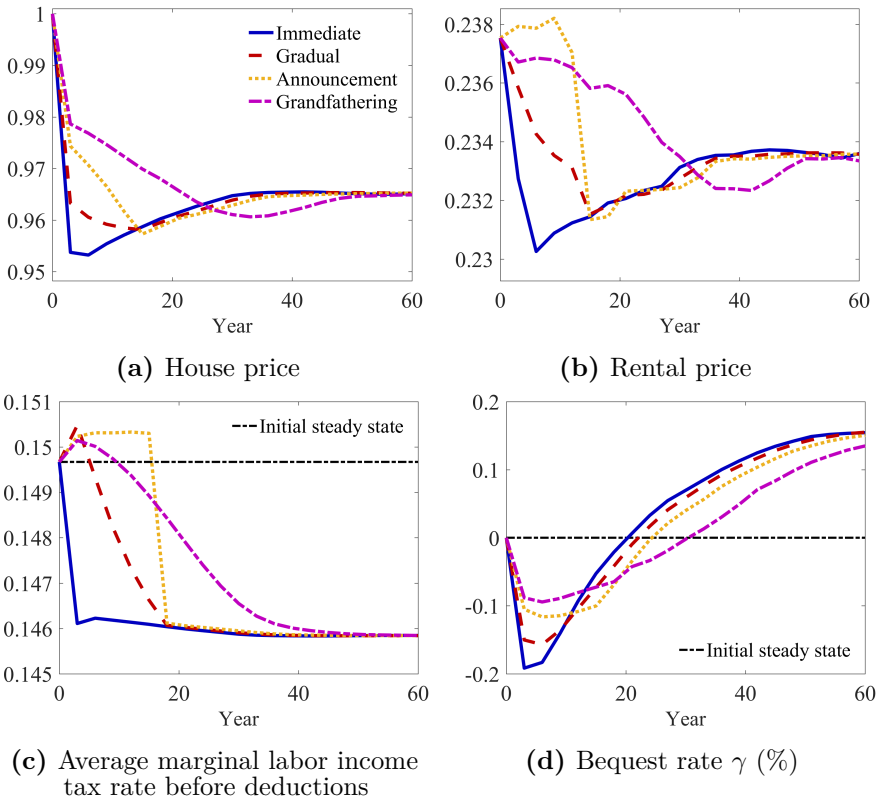


Figure 1.8: Short-run dynamics from removing the MID, across policies

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.

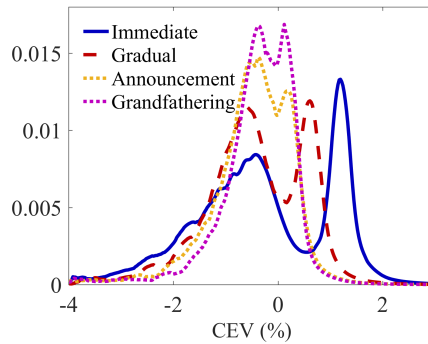


Figure 1.9: Distributions of short-run welfare effects across policies, including grandfathering

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

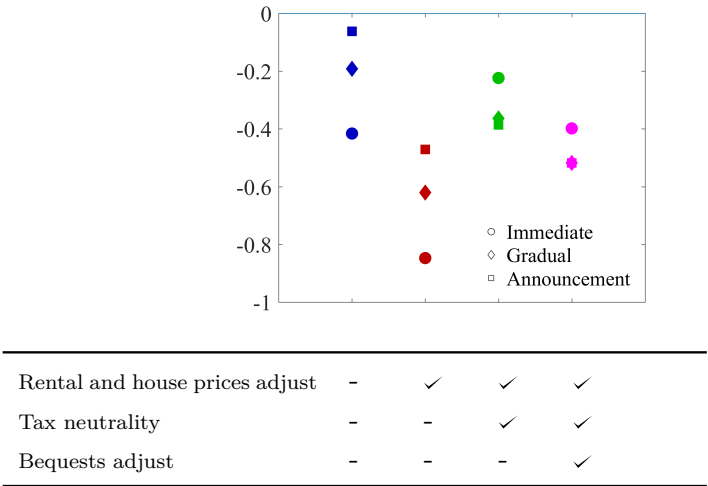


Figure 1.10: Short-run welfare effects under different equilibrium assumptions

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

Mortgage lending standards: implications for consumption dynamics*

*This paper has been jointly written with Karin Kinnerud and Kasper Kragh-Sørensen. We are grateful for helpful discussions with John Hassler, Per Krusell, Kurt Mitman, Monika Piazzesi, Martin Schneider, Karl Walentin, and seminar participants at Stockholm University. We gratefully acknowledge funding from Handelsbanken's Research Foundations, Stiftelsen Carl Mannerfelts Fond, and Torsten Söderbergs Stiftelse. All errors are our own.

2.1 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

¹There 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).

²For 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 housing 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

³We 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.

⁴For 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 cyclical, 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 cyclical 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 2.2 we describe the model, followed by a calibration and comparison to the data in Section 2.3. Section 2.4 presents the results, and Section 2.5 concludes the paper.

2.2 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).

2.2.1 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 $S = \{s, s_2, s_3, \dots, \bar{s}\}$. 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

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

⁶It 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

$$\chi_j = \left(\sum_{k=1}^{M_j} \left[\frac{1}{(1 + r_m)^k} \right] \right)^{-1}. \quad (2.1)$$

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 (2.1) 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,

$$m' \leq (1 - \theta)p_h h'. \quad (2.2)$$

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 ,

$$\chi_{j+1}m' + (\tau^h + \varsigma^I)p_h h' \leq \psi z. \quad (2.3)$$

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.

$$U_j(c, s) = e_j \frac{(c^\alpha s^{1-\alpha})^{1-\sigma}}{1-\sigma}, \quad (2.4)$$

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

$$U^B(q') = v \frac{(q')^{1-\sigma}}{1-\sigma} \quad \text{for } j \in [J_{ret}, J], \quad (2.5)$$

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

$$q' = \frac{b' + p_h h' - m'}{\alpha + (1 - \alpha)p_h}. \quad (2.6)$$

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

⁷The 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.

$$x \equiv \begin{cases} (1+r)b - (1+r^m)m + y - \Gamma - \delta^h h + (1-\varsigma^s)p_h h & \text{if } j > 1 \\ y - \Gamma + a & \text{if } j = 1, \end{cases} \quad (2.7)$$

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.

$$\Gamma \equiv \mathbb{I}^w \tau^{ss} y + \tau^h p_h h + T(\tilde{y}), \quad (2.8)$$

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 2.2.3.

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

$$W_{j+1}(z', x', h', m') = \begin{cases} \mathbb{E}[V_{j+1}(z', x', h', m')] & \text{if } j < J_{ret} \\ \phi_j \mathbb{E}[V_{j+1}(z', x', h', m')] + (1 - \phi_j)U^B(q') & \text{otherwise} \end{cases}$$

subject to

$$\underbrace{c + b' + \mathbb{I}^R p_r s + \mathbb{I}^B (1 + \varsigma^b) p_h h' + \mathbb{I}^{RF, S} (1 - \varsigma^s) p_h h + \mathbb{I}^{RF} \varsigma^r}_{\text{"Expenditures"}} \leq \underbrace{x + m'}_{\text{"Money to spend"}} \quad (2.9)$$

$$\mathbb{I}^{B, RF} m' \leq (1 - \theta) p_h h' \quad \text{LTV constraint}$$

$$\mathbb{I}^{B, RF} \left(\frac{\chi_{j+1} m' + (\tau^h + \tau^I) p_h h'}{z} \right) \leq \psi \quad \text{PTI constraint}$$

$$\mathbb{I}^S m' \leq (1 + r_m) m - \chi_j m \quad \text{Min payment}$$

$$s = h' \quad \text{if } h' > 0$$

$$m' \geq 0 \quad \text{if } h' > 0$$

$$m' = 0 \quad \text{if } h' = 0$$

$$c > 0, s \in S, h' \in H, b' \geq 0.$$

Equation (2.9) 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

$$V_j(z, x, h, m) = \max \left\{ V_j^R(z, x, h, m), V_j^B(z, x, h, m), V_j^S(z, x, h, m), V_j^{RF}(z, x, h, m) \right\}, \quad (2.10)$$

with the policy functions that maximize the Bellman equation for the chosen discrete tenure status

$$\left\{ c_j(z, x, h, m), s_j(z, x, h, m), h'_j(z, x, h, m), m'_j(z, x, h, m), b'_j(z, x, h, m) \right\}.$$

2.2.2 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,

$$p_r = \frac{1}{1+r} \left[rp_h + \delta^r + \tau^h p_h \right]. \quad (2.11)$$

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 return of the investors.

⁸The 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)).

2.2.3 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 (2.8). 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.

$$T(\tilde{y}) = \tilde{y} - \lambda \tilde{y}^{1-\tau^p}, \quad (2.12)$$

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.

2.3 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 have a hard time matching the strong skewness in wealth that we see in 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.

2.3.1 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 2.1. 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
ζ^I	Home insurance	0.005
ζ^b	Transaction cost if buying house	0.025
ζ^s	Transaction cost if selling house	0.07
R	Replacement rate for retirees	0.5
B^{max}	Maximum benefit during retirement	60.4

Table 2.1: Independently calibrated parameters, taken from 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, the 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 , that 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 on both employers and employees. The property tax rate τ^h is taken from the 2009, 2011, and the 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

⁹We 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 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 2.C.

Log earnings for household i of age j are given by

$$\log(y_{ij}) = \alpha_i + g(j) + n_{ij} + \nu_i \quad \text{for } j \leq J_{ret}, \quad (2.13)$$

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,

$$\log(y_{ij}) = \min(\log(R) + \log(z_{i,J_{ret}}), \log(B^{max})) + \nu_i \quad \text{for } j > J_{ret}. \quad (2.14)$$

To estimate equation (2.13) we use PSID data from 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 of 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 2.2.

Parameter	Description	Value
σ_α^2	Fixed effect	0.156
σ_η^2	Permanent	0.012
σ_ν^2	Transitory	0.061

Table 2.2: 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.

2.3.2 Estimated parameters

The parameters that are estimated to match a set of data moments, are listed in Table 2.3. Unless otherwise noted, we use data from the SCF, pooled across the 1989 to 2013 survey years. All the parameters in Table 2.3 are jointly estimated, taking the independently calibrated

parameters in Table 2.1 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
v	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{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 2.3: 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 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{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 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 v 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 preferential tax treatment of owned housing, i.e., mortgage

¹⁰When 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 (2.11). See the Appendices for a detailed description of the solution method and the equilibrium definition.

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. We therefore 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{h} , which is strictly larger than the minimum house size available for rent, is set to match the overall homeownership rate in 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 data compared to the model. Since the tax schedule is continuous in the model, the households are allocated to their nearest tax bracket in data for this calibration exercise. Data on tax rates is taken from Harris (2005).

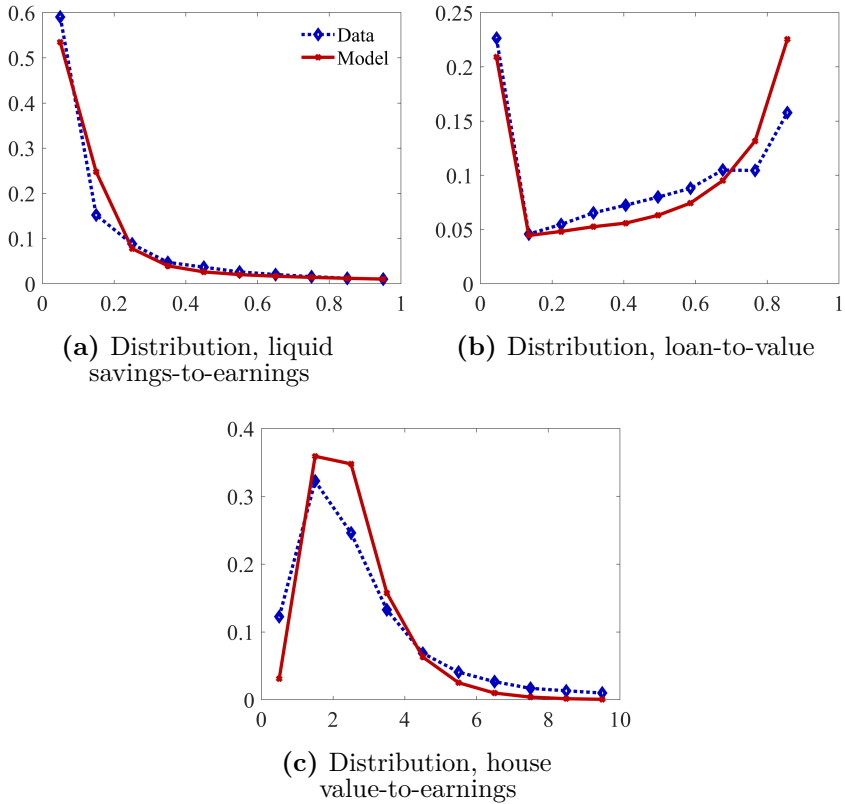


Figure 2.1: Comparison of data versus model: non-targeted distributions
Note: Data is from the SCF, survey years 1989-2013. Model refers to the baseline economy. In Figure 2.1a and Figure 2.1c, only working-age households are included, and Figure 2.1b displays only homeowners.

2.3.3 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 how much equity is available in the house, and if increased mortgage

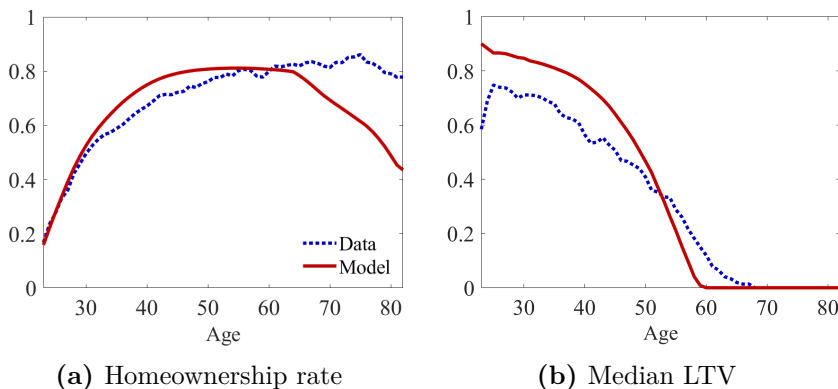


Figure 2.2: Comparison of data versus model: non-targeted life-cycle profiles

Note: Data is from the SCF, survey years 1989-2013. Model refers to the baseline economy. The median LTV is computed among homeowners.

financing is possible. In Figure 2.1, 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, 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 2.2.

2.4 Results

Equipped with our model, we now turn to the quantitative analysis. We start by carefully analyzing the determinants of MPCs in our baseline model. We then consider how permanent and temporary

¹¹We 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 of 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 of mortgages.

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

$$MPC_{ij} \equiv \frac{c_{ij}(z, x + \Delta_x, h, m) - c_{ij}(z, x, h, m)}{\Delta_x}, \quad (2.15)$$

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 the 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 would have been a renter, but chooses to become a homeowner due to the wealth shock.

¹²We think of a negative wealth shock as representing an economic downturn, though admittedly a stylized one.

2.4.1 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 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 2.3 shows that there is considerable heterogeneity in MPCs across households. At the right 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.

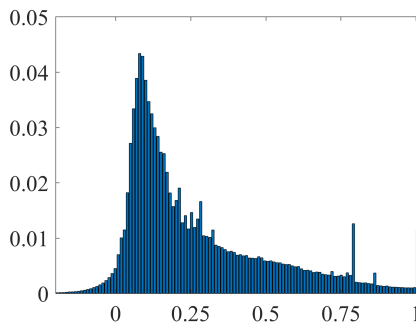


Figure 2.3: Distribution of MPCs

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

¹³Hereafter, 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 key determinants of MPCs.

Figure 2.4a 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 2.3. 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 tail in Figure 2.3. 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 stipulated by their amortization plan, and can thus adjust by paying off less in response to the shock.

In Figure 2.4b, we show that households with higher transitory income tend to have lower MPCs. This observation complements the findings in Figure 2.4a. 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 household 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. They therefore 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 2.3 that we have not discussed thus far, is the large portion of households with an MPC of around 0.1. Our results in Figure 2.4a and Figure 2.4b, indicate that these are households with 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.

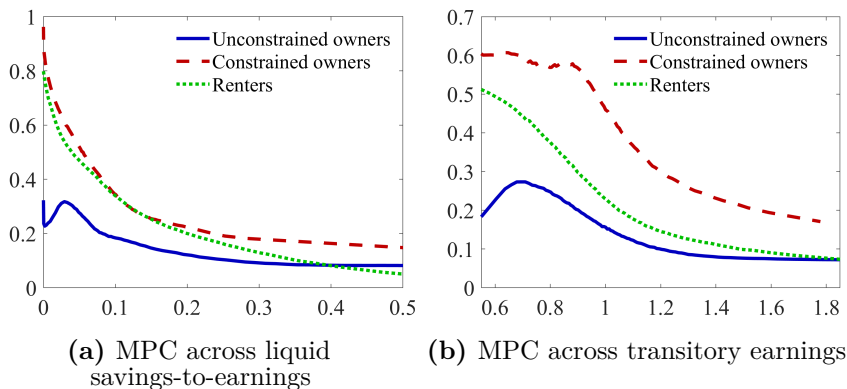


Figure 2.4: Decomposing the mean MPC of non-switchers

Note: MPCs for working-age households from a wealth shock of $-1,000$ dollars

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 2.3. 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 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 low transitory income. Once these households access their housing equity, they increase their consumption significantly.

In Figure 2.5, we decompose the effects of non-switchers and switchers for the mean MPC across shock sizes. Figure 2.5a 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 2.5b, 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

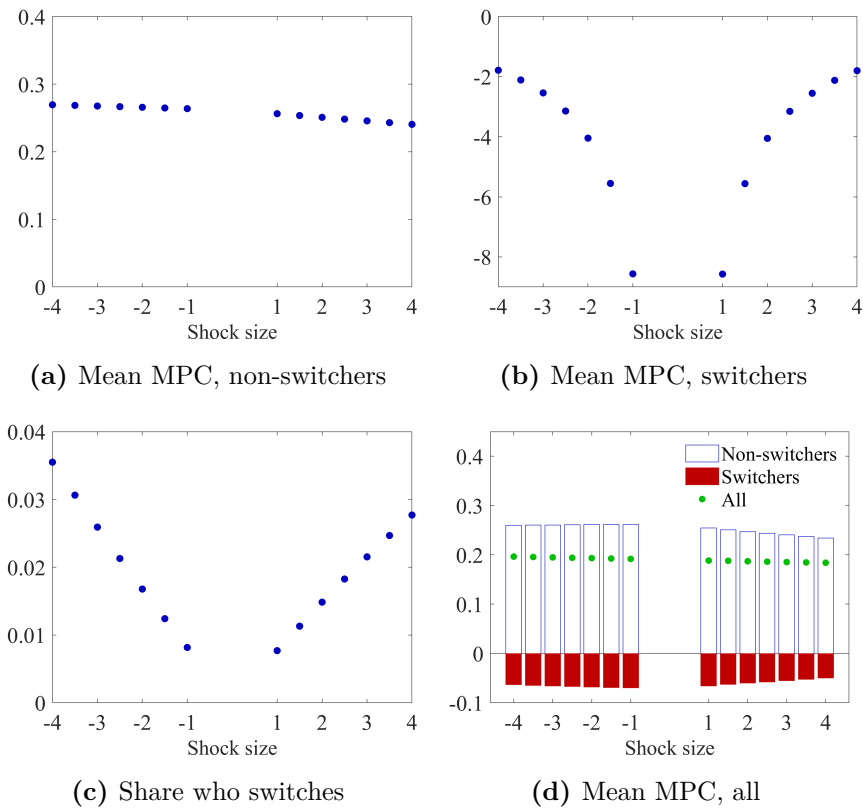


Figure 2.5: Decomposing the mean MPC across shock size (thousands of dollars)

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

¹⁴See Appendix 2.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 2.5d 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 2.5c. 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 wealth shocks than for positive. This off-sets the slight fall in MPCs among non-switchers as the shock becomes larger and positive.

2.4.2 Permanent changes in LTV and PTI

As the previous section shows, there is 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 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 2.4 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 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 2.4: Steady-state prices and moments under permanent changes in lending policies

¹⁵The pair of policies were chosen such that the percentage change in house prices is roughly the same.

Although 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 2.6a shows the aggregate consumption dynamics up to 10 years after a wealth shock of $-4,000$ dollars.¹⁶ There are virtually no differences in dynamics across policies. In Appendix 2.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 2.6b 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 the baseline model, as seen in Appendix 2.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 2.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 2.4.

¹⁶We assume that the shock is unexpected. To focus on the direct demand effect, we assume that prices are constant during the transition.

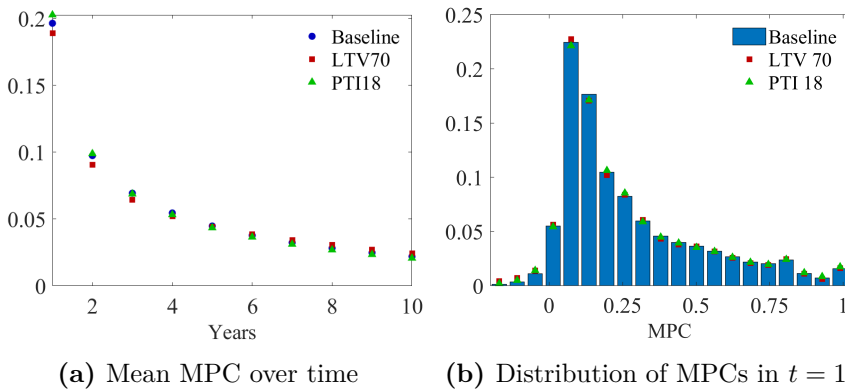


Figure 2.6: MPCs for different permanent policies

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.

2.4.3 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 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 lending standards are back to normal in the next period.

The main role of the temporary policy is to reallocate consumption

over time. Because we abstract from price changes in this part of the analysis, cumulative consumption over time is going to 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 is able to lower 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 lowers 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 as 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 2.7a 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

¹⁷Note 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 2.7b 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 possible to get strong consumption responses from a temporary change in PTI too. 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.

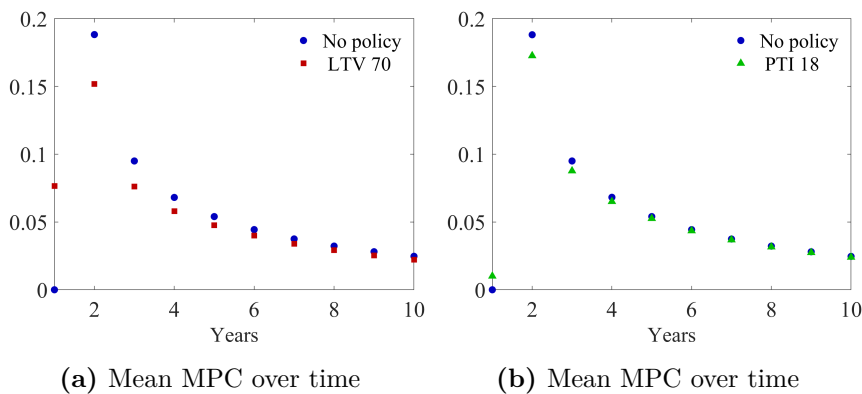


Figure 2.7: MPCs for different temporary LTV and PTI policies

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 causes them to increase their savings, 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 Though, 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 2.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

¹⁸A more thorough description of the welfare measure is provided in Karlman et al. (2020).

¹⁹As 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.

a CEV of zero. At the household level, the welfare effects can be substantial. Figure 2.8 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.

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 2.8a shows that households whose permanent income is about 20 percent lower than expected have a mean welfare gain of 0.2 percent. Similarly, Figure 2.8b shows that households with very low transitory income have a mean welfare gain of more than 0.6 percent. As indicated by the hollow markers in Figure 2.8, 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.

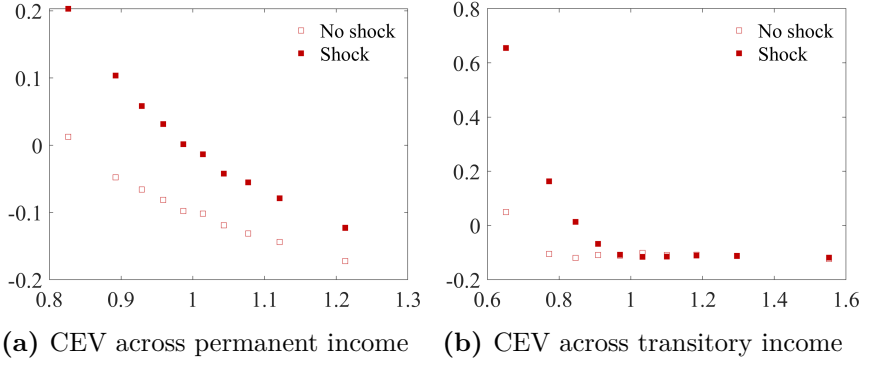


Figure 2.8: Mean CEV (%) with or without wealth shock in $t = 2$

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 $t = 2$.

To shed 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 absent the policy would choose a larger mortgage. 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 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 is 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 2.13 in Appendix 2.D.3 shows that temporary stricter LTV and PTI requirements continue to dampen 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, compared to a scenario without a boom phase. For example, when the wealth shocks are of size 12,000 dollars, the optimal LTV and PTI policies are 0.8 and 0.18, respectively. Recall that with no boom phase, 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

²⁰ Admittedly, this example is highly stylized, but it still offers valuable insights of the effects of temporary policies.

to leave lending standards unchanged. This is the case, for example, 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, 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.

2.5 Concluding remarks

Since the Great Recession, policymakers in many countries have considered and implemented stricter mortgage lending standards. These policies aim to lower household debt and, ultimately, to reduce 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 consumption responses to shocks, but it does not come without costs. Specifically, we find that LTV and PTI requirements introduced in a period before a downturn, reduce the consumption fall during the bust. However, in order 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.

References

- Aastveit, K. A., E. Getz Wold, and R. Juelsrud (2020). Mortgage regulation and financial vulnerability. *Presented at the Nordic Junior Macro Seminar, May 27th*.
- Angelini, P., S. Nicoletti-Altimari, and I. Visco (2012, November). Macroprudential, microprudential and monetary policies: conflicts, complementarities and trade-offs. Occasional Paper No. 140, SSRN.
- Bell, F. C. and M. L. Miller (2005, August). Life tables for the United States Social Security Area 1900-2100. Actuarial study No. 120, Social Security Administration.
- Boar, C., D. Gorea, and V. Midrigan (2020). Liquidity constraints in the U.S. housing market. *Working Paper*.
- Carroll, C. D. and A. A. Samwick (1997). The nature of precautionary wealth. *Journal of Monetary Economics* 40(1), 41–71.
- Chen, H., M. Michaux, and N. Roussanov (2020). Houses as atms: mortgage refinancing and macroeconomic uncertainty. *The Journal of Finance* 75(1), 323–375.
- Cho, S.-W. and J. Francis (2011). Tax treatment of owner occupied housing and wealth inequality. *Journal of Macroeconomics* 33, 42–60.
- Cocco, J. F., F. J. Gomes, and P. J. Maenhout (2005). Consumption and portfolio choice over the life cycle. *Review of Financial Studies* 18(2), 491–533.
- Díaz, A. and M. J. Luengo-Prado (2008). On the user cost and homeownership. *Review of Economic Dynamics* 11(3), 584–613.

- Druedahl, J. and T. H. Jørgensen (2017). A general endogenous grid method for multi-dimensional models with non-convexities and constraints. *Journal of Economic Dynamics and Control* 74, 87–107.
- Ferrero, A., R. Harrison, and B. Nelson (2018, December). House price dynamics, optimal ltv limits and the liquidity trap. Discussion Paper No. DP13400, CEPR.
- Floetotto, M., M. Kirker, and J. Stroebel (2016). Government intervention in the housing market: who wins, who loses? *Journal of Monetary Economics* 80, 106–123.
- Gervais, M. (2002). Housing taxation and capital accumulation. *Journal of Monetary Economics* 49(7), 1461–1489.
- Greenwald, D. (2018). The mortgage credit channel of macroeconomic transmission. *Working Paper*.
- Gruber, J. W. and R. F. Martin (2003). Precautionary savings and the wealth distribution with illiquid durables. *International Finance Discussion Papers* 773.
- Harding, J. P., S. S. Rosenthal, and C. Sirmans (2007). Depreciation of housing capital, maintenance, and house price inflation: estimates from a repeat sales model. *Journal of Urban Economics* 61(2), 193–217.
- Harris, E. (2005, November). Effective marginal tax rates on labor income. A CBO paper, Congressional Budget Office.
- Heathcote, J., K. Storesletten, and G. L. Violante (2017). Optimal tax progressivity: an analytical framework. *Quarterly Journal of Economics* 132(4), 1693–1754.

- Kaplan, G., K. Mitman, and G. Violante (2020). The housing boom and bust: model meets evidence. *Journal of Political Economy*, Forthcoming.
- Kaplan, G. and G. Violante (2014). A model of the consumption response to fiscal stimulus payments. *Econometrica* 82(4), 1199–1239.
- Karlman, M., K. Kinnerud, and K. Kragh-Sørensen (2020). Costly reversals of bad policies: the case of the mortgage interest deduction. *Working Paper*.
- Lim, C. H., A. Costa, F. Columba, P. Kongsamut, A. Otani, M. Saiyid, T. Wezel, and X. Wu (2011, October). Macroprudential policy: what instruments and how to use them? Lessons from country experiences. IMF Working Paper No. 11/238.
- Mian, A. and A. Sufi (2014). *House of debt: how they (and you) caused the Great Recession and how we can prevent it from happening again*. University of Chicago Press, Chicago.
- Piazzesi, M. and M. Schneider (2016). Housing and macroeconomics. *Handbook of Macroeconomics* 2, 1547–1640.
- Sommer, K. and P. Sullivan (2018). Implications of US tax policy for house prices, rents, and homeownership. *American Economic Review* 108(2), 241–74.

2.A Definitions of stationary equilibrium

Households are heterogeneous with respect to age $j \in \mathcal{J} \equiv \{1, 2, \dots, J\}$, permanent earnings $z \in \mathcal{Z} \equiv \mathbb{R}_{++}$, mortgage $m \in \mathcal{M} \equiv \mathbb{R}_+$, owner-occupied housing $h \in \mathcal{H} \equiv \{0, \underline{h}, \dots, \bar{h} = \bar{s}\}$, 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 $\mathcal{B}(\mathcal{U}) \equiv \mathbf{B}(\mathbb{R}_{++}) \times \mathbf{B}(\mathbb{R}_+) \times P(\mathcal{H}) \times \mathbf{B}(\mathbb{R}_{++})$. Further, let \mathbb{M} be the set of all finite measures over the measurable space $(\mathcal{U}, \mathcal{B}(\mathcal{U}))$. Then $\Phi_j(U) \in \mathbb{M}$ is a probability measure defined on subsets $U \in \mathcal{B}(\mathcal{U})$ 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 (2.10) 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 (2.11).
3. The quantity of the total housing stock is given by the total

demand for housing services²¹

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

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 $Q_j : \mathcal{U} \times \mathcal{B}(\mathcal{U}) \rightarrow [0, 1]$ 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, 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 (2.10) 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 (2.11).

²¹We 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:

$$H = \bar{H}$$

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

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 $j < J$

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

2.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 G²EGM 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.

2.C Labor income process

2.C.1 Data sample

Equation (2.13) 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).

2.C.2 Estimation

In this section, we describe how the exogenous earnings process in equation (2.13) 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_α^2 , the permanent shock σ_η^2 , and the transitory shock σ_ν^2 .

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_ν^2) and permanent (σ_η^2) 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.

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

where the equality follows from equation (2.13). Define r_{id} as household i 's d -period difference in $\log(y_{ij}^*)$,

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

Since the transitory and permanent shocks are i.i.d., it follows that

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

These variances are estimated by running an OLS regression of $\text{Var}(r_{id}) = r_{id}^2$ 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 $\hat{\sigma}_\alpha^2$ is given by the residual variance in period $j = 1$,

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

2.D Additional results

2.D.1 Baseline model

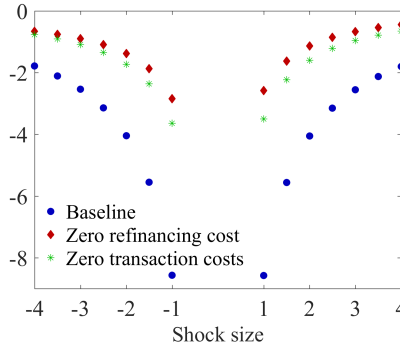


Figure 2.9: MPCs of switchers: no refinancing costs or transaction costs

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.

2.D.2 Permanent policies

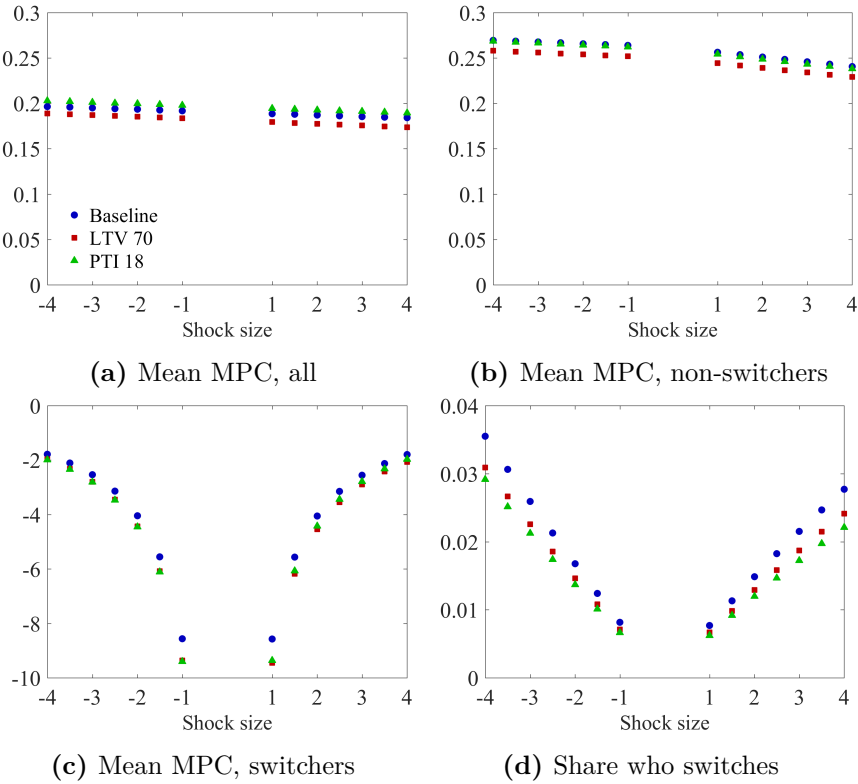


Figure 2.10: Decomposing the mean MPC across shock size (thousands of dollars)

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 2.5: Steady-state prices and moments under permanent changes in the lending policies

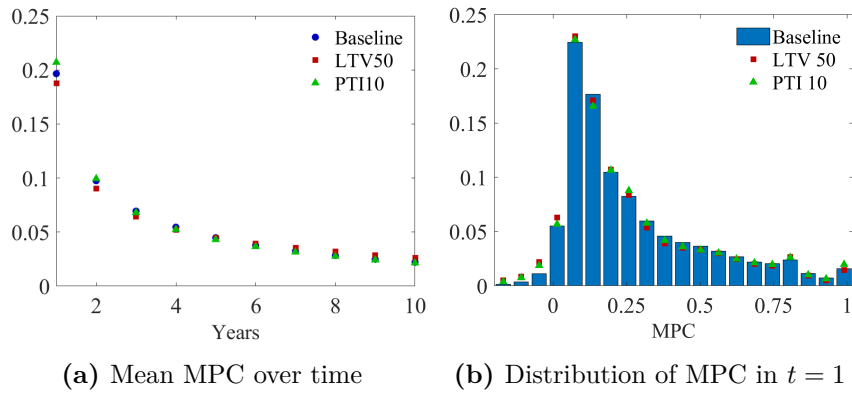


Figure 2.11: MPCs for different permanent policies

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.

2.D.3 Temporary policies

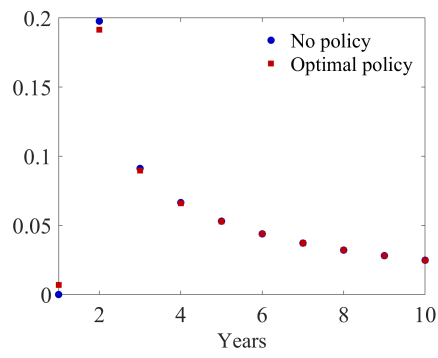


Figure 2.12: Mean MPC, for optimal temporary loan-to-value policy, over time

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.

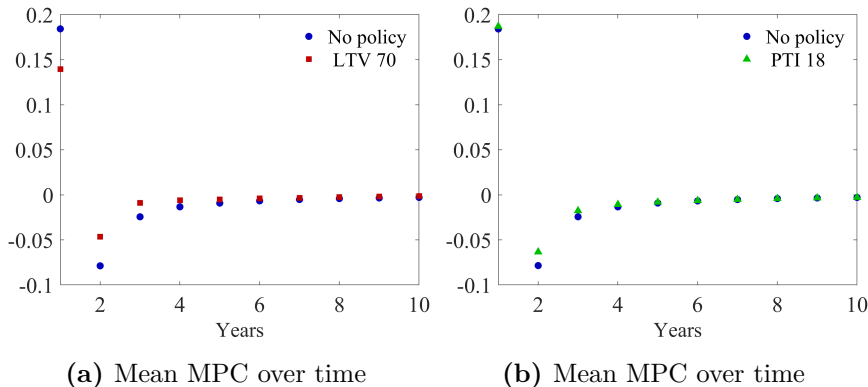


Figure 2.13: MPCs for temporary LTV or PTI policy in boom-bust episode

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.

Chapter 3

The great house price divergence: a quantitative investigation of house price fundamentals*

*I am grateful for helpful discussions with John Hassler, Per Krusell, Kieran Larkin, and Kurt Mitman. All errors are my own.

3.1 Introduction

The dramatic increase in house prices of the past decades in the U.S. has been accompanied by a significant divergence of prices across regions. Figure 3.1a plots the U.S. national resale index of house prices provided by Freddie Mac, deflated by the non-housing part of CPI. Prices remained fairly stable until the mid-90's, after which they started increasing more rapidly and are now around 50% higher than in 1995.¹ At the local level, the picture is more complicated. Figure 3.1b shows how real house prices, also measured using the Freddie Mac house price index (FMHPI), have developed across metropolitan areas (MSAs) in the U.S. between 1995 and 2018. While there has been an increase on average, regional prices range from being slightly lower to being over twice as high as 23 years earlier. Figure 3.1c further reveals that locations that have seen huge price increases are often areas that had high prices to begin with. In other words, house prices have diverged. Concurrent with the increase in the national price index, the divergence started in the middle of the 1990's, as shown in figure 3.1d.

In this paper, I investigate the causes and effects of these changes. Why have house prices increased? Why have local prices diverged? And who are the winners and losers of these developments? To answer these questions I build and calibrate a general equilibrium model with heterogeneous agents. I use the model to quantify the relative importance of three fundamental factors for explaining house prices during this time period. These are local wages, the real interest rate, and local housing supply elasticities. Feeding in changes to these fundamentals in the model allows me to quantify the role that each of

¹Knoll et al. (2014) show that this pattern holds for the vast majority of developed countries, and that the years around the turn of the millennium stand out historically as the time period with the fastest growing house prices in modern history. The two notable exceptions are Germany and Japan.

them plays in determining house prices. I finally quantify the welfare gains and losses for the different households in the economy, resulting from these changes in fundamentals.

The main result of this paper is that most of the divergence of house prices at the local level and the increase in the national house price index can be explained by a combination of higher and more dispersed wages, and a lower real rate. Both wages and the interest rate are important for explaining both the increase and divergence of house prices. Furthermore, the endogenous location choice is key for these results. The increased spatial wage differences and the lower interest rate both lead to a desire among households to migrate to regions where houses are expensive. The supply of housing limits how much migration can actually take place. In equilibrium, prices adjust to clear the housing markets, leading to a divergence of local house prices. Although the model predicts a large long-run response in terms of households' location choices, the forward-looking nature of households in combination with moving costs make prices respond quickly to changes in house price fundamentals, without much migration taking place in the short run. This helps align the model with the data, where prices have changed significantly while fairly little interregional migration has taken place thus far. The quick and large increase in home values in expensive regions lead to significant welfare gains among homeowners in expensive locations. When quantifying these welfare gains, they are equivalent of receiving a lump-sum transfer of several years worth of labor earnings. The supply side is important for the equilibrium location choices and the average house price, but it does not affect the model's prediction for the divergence of local house prices much. The intuition is that house prices act as a compensating differential. The relative house price has to adjust such that the marginal household is indifferent between living in either region.

I arrive at these results by building and calibrating a Rosen-Roback model with heterogeneous agents of the Bewley-Huggett-

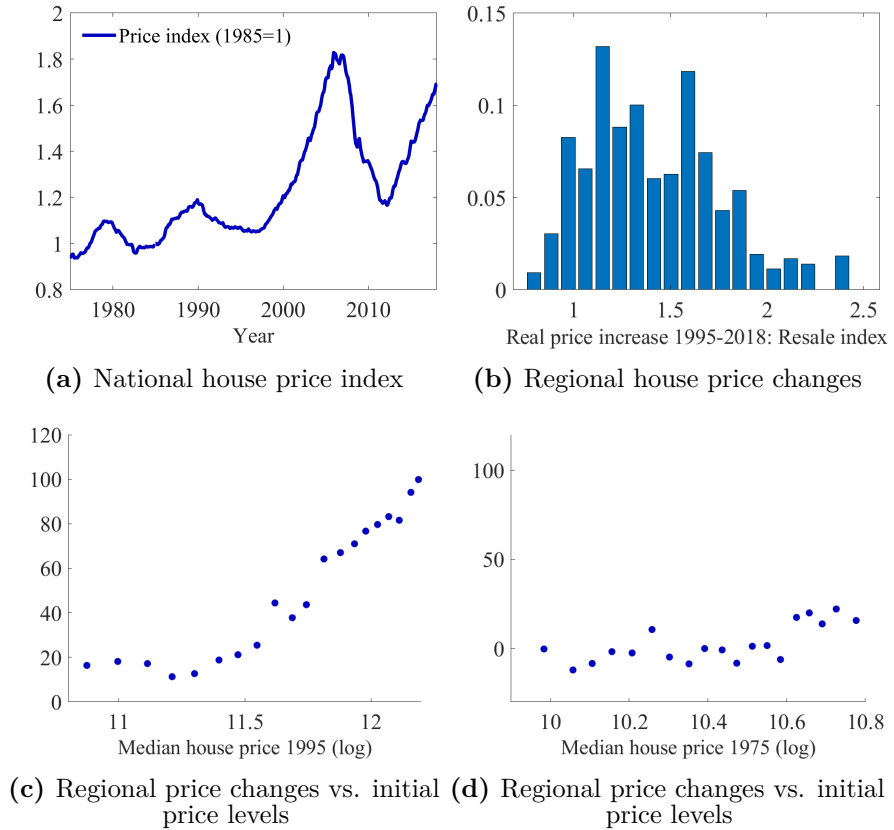


Figure 3.1: The Great House Price Divergence

Note: Figure 3.1a shows the Freddie Mac House Price Index, deflated by the non-housing part of CPI, for the United States. Figure 3.1b illustrates the changes in the FMHPI, deflated by national non-housing CPI, for all 383 MSAs for which the data is available over the years 1995 to 2018. The histogram is unweighted. Figure 3.1c plots the percentage change in the FMHPI between 1995 and 2018, for 20 bins of MSAs, against the logarithm of the median house value in 1995 as provided by the American Community Survey (ACS). Figure 3.1d repeats the exercise and plots the change in real house prices between 1975 and 1995 against the median house price in 1975.

Aiyagari type. To plausibly quantify the role of the different house price fundamentals, the model features a detailed specification of the

housing market and the determinants of housing demand. Households endogenously choose how much housing to consume, and whether to own or rent. Owned housing comes with transaction costs, but is preferred due to preferential tax treatment and a lower maintenance cost. An owned house can be used as collateral for borrowing, but only subject to exogenously imposed loan-to-value and payment-to-income requirements. Moreover, mortgages come with a pre-specified repayment plan, forcing the homeowner to save in housing equity each period. This type of model has in recent years become the standard tool for analysing housing related questions in the macro literature. I am the first to add a spatial dimension to this framework, where different regions have both separate housing and labor markets. The model has two geographical regions and households are free to move between them subject to a moving cost. Equilibrium is ensured by letting house prices and location choices be determined endogenously.

The role of wages in driving house prices is fairly intuitive. Wages have gone up substantially in some areas, while in other areas wages have increased at a much slower pace. Since housing is a normal good, demand increases more in areas where wages increase the most. In addition, households want to move to high-wage areas; an extensive margin response that increases demand for housing in areas with increasing wages, and lowers demand elsewhere. I use data from the U.S. Census and the American Community Survey to calculate the change in the wage level for all MSAs. I then feed in changes to labor productivity in my model that replicate these changes, and solve for the equilibrium changes in house prices and migration. Wages are able to explain 61.9% of the divergence of house prices and 41.4% of the increase in the national house price index between 1995 and 2018.

The next most important contributor to changes in house prices is the lower real interest rate. The channel from a lower interest rate to higher house prices works through the expenditure side. A lower interest rate drives up the demand for housing, and thus house prices,

by lowering the opportunity cost of housing equity and the cost of mortgage financing. Although the fall in the real rate is a global phenomenon (King and Low, 2014), I show that it has a differential impact on house prices across locations. In particular, it has a larger impact on the demand for housing in expensive areas where households have large mortgages and large amounts of housing equity, compared to places where houses are cheap. This differential impact not only increases housing demand more in MSAs where houses are expensive, but it also creates a desire among households to move to these locations. In other words, the lower real interest rate is not only a driver of house prices, but also a driver of interregional migration. When I change the interest rate in my model in line with data, the interest rate explains 32.2% of the increase in the national house price level and 20.2% of the divergence.

The last fundamental that I explore is local housing supply elasticities. As pointed out in several articles, recently by Glaeser and Gyourko (2018), expensive regions have house prices that far exceed the marginal cost of building additional housing. This tells us that the supply elasticity is to a large degree driven by policies on land use and building standards, which in turn means that the supply of housing can be altered. In the model, the house price is determined by the intersection of housing demand and housing supply. By having the supply of housing explicitly modelled, I can investigate how changes in the elasticity of housing supply affects the average house price level, relative house prices, and migration patterns. I conclude that larger differences in the elasticity across regions lead to smaller responses in terms of migration, as fewer households migrate to the expensive MSAs when fundamentals change. I also find that this has little impact on house price dispersion, as the relative price is pinned down as a compensating differential making the marginal household indifferent between living in either of the two regions.

This paper proceeds as follows. Section 2 relates my work to

the literature. Section 3 discusses the role of wages and the real interest rate in an as-simple-as-possible framework, highlighting the effect of these two variables on the dispersion in house prices. Section 4 introduces the full model and relates it to the data. The model is calibrated in section 5 to fit moments for the U.S. economy in the early 1990's. Section 6 delivers the results. Section 7 concludes.

3.2 Related literature

This paper adds to the rapidly growing strand of literature using heterogeneous agent models with idiosyncratic income risk to answer questions related to housing. In the macro-housing literature, this type of framework has become the standard tool for analysing most types of questions related to housing. Recently, this class of models has been used to study the tax treatment of housing (e.g., Floetotto et al. (2016), Sommer and Sullivan (2018)), the boom-and-bust cycle of house prices (e.g., Kaplan et al. (2020), Garriga and Hedlund (2017)), trends in the homeownership rate (e.g., Chambers et al. (2009)), and the transmission mechanism of monetary policy (e.g., Hedlund et al. (2016)). My paper is most closely related to work on the role of house price fundamentals for determining house prices in this type of framework. Kiyotaki et al. (2011) highlight the effect of the land share in production of tangible assets, including housing, and show that a high land share makes house prices more responsive to aggregate shocks. They find that wages and interest rate changes can account for roughly half of the price increase between 1995 and 2006. Most closely related to my work is Sommer et al. (2013). They also study the impact of increased wages and lower interest rates on house prices and rents. They find that wages and interest rates can account for roughly half of the observed increase in house prices between 1995 and 2006, while financial constraints have no effect on the house price. Apart from looking at a more recent time period, the major difference

between their work and mine is the spatial dimension. By adding a second region to the model and allowing for endogenous migration between them, I can investigate the evolution of house prices at both the national and the regional level. I also use a richer framework in terms of modelling the mortgage market, by modelling mortgages as long-term contracts with multiple constraints.

My paper can also be placed in the literature studying location choices in a setting of heterogeneous regions. This class of models are often referred to as Rosen-Roback models, after the papers of Rosen (1979) and Roback (1982), highlighting that house prices reflect spatial differences in amenities or other traits. Among these other traits, the role of wages has undoubtedly received the most attention. A long list of papers highlight the endogenous response of both wages and housing costs to local labor demand shocks, and is thoroughly reviewed in Moretti (2011). Another strand of literature has focused on local amenities as a driver of house price dispersion, and has lately made the claim that these are endogenous to the demographic composition of the area. This line of research is well summarized in Diamond (2016), who also makes a large contribution in her paper. The only paper, to my knowledge, that aims to explain the increased dispersion of house prices in a dynamic model with heterogeneous regions and households is van Nieuwerburgh and Weill (2011). Their model does not include ownership, financing decisions, idiosyncratic risk, or financial constraints. It also has very stark implications for sorting on skill, and focuses on a much earlier time period than I do. Their finding is that changes in local wages can explain the entire increase in price dispersion. In contrast, while I find this channel to be important it is far from sufficient to explain all of the divergence that we see in the data. Moreover, they do not discuss the role of the interest rate at all.

A separate segment of the housing literature has approached regional house prices empirically. Significant effort has been focused

on the role supply side restrictions, asking whether scarcity is driven by natural constraints or land use regulation. This line of research has consistently found that the latter is far more important. This is often done by comparing house prices to the cost of constructing new houses.² Glaeser and Gyourko (2003) show that land purchased to expand existing lots are cheaper than land purchased to construct new buildings. Glaeser et al. (2005) show that the cost of adding one unit of housing on top of existing residential buildings in Manhattan is only half of the market price. Glaeser and Gyourko (2018) compare construction costs to house prices across metropolitan areas in the U.S. and show that prices exceed construction costs in all expensive regions, and that construction costs are constant across regions. Gyourko et al. (2008) approach the role of land use restrictions more directly by surveying local governments across the U.S., documenting which land use restrictions they employ. The answers are then transformed into the Wharton Residential Land Use Regulation Index, which they show correlates well with house prices. Saiz (2010) uses satellite data on natural constraints to building, and claims that both natural and policy-induced constraints matter for housing supply. Furthermore, he quantifies the elasticity of housing supply to prices for different areas in the U.S., and shows how this is inversely correlated to house prices. I use his results as a baseline calibration of the supply elasticities in my model. Others have also tried to quantify construction costs over time. The consensus view is that construction costs have been remarkably stable, implying that the increase in the average house price and the price dispersion is entirely driven by land rents. Glaeser and Gyourko (2018) documents this for the United States. Knoll et al. (2014) construct a price index and an index of construction costs for

²If the supply side was unregulated, any deviation of prices from marginal costs would imply there is money on the table and lead to an increase in supply. Naturally scarce land would simply force developers to construct taller and denser buildings, leading to an increase in the marginal cost.

14 developed countries, going all the way back to 1870. They too show that construction costs have remained stable since 1970, not just in the U.S. but in all their sampled countries. Davis and Palumbo (2008) decompose the house price for several large American cities into the price of land and the price of structure. They show that both the marginal cost of constructing housing and the price of the structure has remained virtually unchanged over time. However, all regions have experienced a significant increase in land prices, on average 105% between 1998 and 2004.

In terms of empirical work that directly estimates the effect of fundamentals on house prices, the literature is sparse. A notable exception is Hornbeck and Moretti (2019) who estimate the impact of local productivity changes on house prices, wages, and labor supply using an instrumental variable approach. They find that local labor supply increases by 3% following a 1% increase in wages, and that this increase takes two decades to materialize. This shows that workers are fairly responsive to wages in their migration decisions, and the quantitative estimate is consistent with what I find in this paper.

3.3 A simple model

The bulk of this paper is dedicated to constructing a heterogeneous agent framework without any closed form solutions, and solving it using computational methods. To motivate this exercise and provide intuition for the main results, this section uses a framework that is as simple as possible to highlight the mechanisms behind the results. As higher wages and lower rates driving up housing demand is fairly obvious, I will focus on the role of these forces in explaining house price dispersion.

3.3.1 Model setup

Consider a single representative household who chooses consumption c , housing s , and location q to solve the following static problem

$$\max_{c,s,q} \frac{(c^\alpha s^{1-\alpha})^{1-\sigma}}{1-\sigma} \quad s.t. \quad c + P_r(q)s = w(q),$$

where $P_r(q)$ and $w(q)$ is the rent and wage in region q . Conditional on location, this is a standard bivariate optimization problem. The Cobb-Douglas aggregator nested in the CRRA utility function ensures that households will spend a constant share α and $1 - \alpha$ on consumption and housing, regardless of location. For there to be an interior solution, we require the indirect utility function for each location to have the same value. This yields a relationship between wages and rents

$$\frac{P_r(q)}{P_r(q')} = \left(\frac{w(q)}{w(q')} \right)^{\frac{1}{1-\alpha}}. \quad (3.1)$$

Since locations differ by wages and rents, any difference in one of these variables has to be compensated for by the other. In essence, the only reason why anyone would live in a high rent region like Boston is that wages are sufficiently high there to compensate for the cost of living.

Equation (3.1) tells us that wage dispersion and rent dispersion are related, but says nothing about house prices or the interest rate. To remedy this, we need to put some structure on the rent. Suppose all rental housing is owned by deep pocket investors outside the model, who also have the opportunity to invest in some risk-free asset at the interest rate r . If the investors want to maximize profits and the rental market is competitive, the return to owning rental housing has to be the same as any alternative form of investment. This implies the following relationship between rents, the interest rate, and house

prices

$$P_r(q) = \frac{1}{1+r} (\delta + rP_h(q)), \quad (3.2)$$

where $P_h(q)$ is the local house price and δ is an operating expense of maintaining the property and providing rental services. Discounting aside, equation (3.2) says that the rent has to offset two costs that accrue to the landlord. It has to cover the operating expense δ , and it has to cover the opportunity cost of the invested capital $rP_h(q)$.

An equivalent way of thinking about (3.2) is as an equation for the user cost of housing. If the household owns the house it lives in, rather than paying a rent every period, it has to pay the two costs in the right-hand side of (3.2) directly. Effectively, a homeowner is his own landlord. In terms of terminology, $P_r(q)$ is then referred to as the user cost of housing, a convention I will stick to throughout the rest of this section.

A key assumption in (3.2) is that the operating cost is independent of location and price. This is motivated by this cost being associated with maintaining the physical building. As discussed in the section on previous literature, the cost of constructing new housing is known to be roughly constant across space and time, which suggests that assuming the same for maintaining existing houses is not far fetched. In section 3.4.7 I will provide direct evidence on this by comparing reported maintenance expenditure across locations and over time in the U.S. For now, note that this assumption implies that any difference in the user cost has to come from differences in the opportunity cost, i.e., from dispersion in prices. Since these price differences are not based on differences in the maintenance cost, one can think of them as land rents. House prices, and rents, are not high in Boston because the technology to construct and maintain houses is intrinsically different from that in rural Kansas. Houses are expensive because land is scarce in Boston, leading to land upon which houses stand to be very

expensive. This line of reasoning summarizes the main findings in Davis and Palumbo (2008), who show huge differences in land rents across the U.S. and that these correlate very well with house prices.

3.3.2 Results

To think about price dispersion, it is helpful to combine (3.2) and (3.1) to obtain

$$\Delta^P = \left((\omega + 1)^{\frac{1}{1-\alpha}} - 1 \right) \left(\frac{\delta}{rP_h(q')} + 1 \right), \quad (3.3)$$

where price dispersion Δ^P and wage dispersion ω are defined as

$$\begin{aligned} \omega &\equiv \frac{w(q) - w(q')}{w(q')} \\ \Delta^P &\equiv \frac{P_h(q) - P_h(q')}{P_h(q')}, \end{aligned}$$

and where q and q' denote two different regions. The first bracket simply relates price dispersion to wage dispersion. If $P_h(q) > P_h(q')$ then $w(q) > w(q')$ is required to ensure that households are indifferent between the two regions. The second bracket is positive, and relates the price dispersion to the share of land rents in the user cost. From (3.3) we can derive some key results relating house price dispersion to wages and the interest rate.

- Increased wage dispersion increases price dispersion

$$\frac{\partial \Delta^P}{\partial \omega} = \frac{1}{1-\alpha} (\omega + 1)^{\frac{\alpha}{1-\alpha}} \left(\frac{\delta}{rP_h(q')} + 1 \right) > 0$$

- A lower interest rate increases price dispersion

$$\frac{\partial \Delta^p}{\partial r} = - \left((\omega + 1)^{\frac{1}{1-\alpha}} - 1 \right) \frac{\delta}{r^2 P_h(q')} < 0$$

- As the interest rate approaches zero, price dispersion explodes

$$\lim_{r \rightarrow 0} \Delta^p = +\infty$$

The first result should not come as a surprise. Prices have to change such that the household is indifferent between all regions. When wages become more dispersed, prices also have to become more dispersed. The relationship between the interest rate and price dispersion is more subtle. To ensure equilibrium, according to (3.1) the ratio of user costs has to remain constant. When the interest rate falls, the user cost falls in both regions. However, since the opportunity cost is the product of the interest rate and the house price, the user cost will fall more in the expensive region. To offset this, prices have to become more dispersed. The last result is the extreme case of this. When the interest rate approaches zero, the opportunity cost also goes to zero no matter how much the house is worth. The user cost of housing is then $P_r = \delta$, the price-invariant maintenance cost that is associated with the structure. Prices do not affect the cost of housing, making the high-wage region superior to the low-wage region for all house price levels. There is no interior solution.

By putting numbers into equation (3.3), the model can make quantitative statements regarding the effect of wages and the interest rate on house price dispersion. I use the same values as in the full model, which are discussed in detail in section 3.5. This means setting $\delta = 0.0135$, $\alpha = 0.68$ and $P_h(q') = 0.792$. Figure 3.2 shows the equilibrium values of house price dispersion for a range of values of ω and r . In 3.2a I hold r constant at 4%, and in 3.2b I hold ω constant

at 0.1198, both of which are consistent with the calibration in section 3.5.

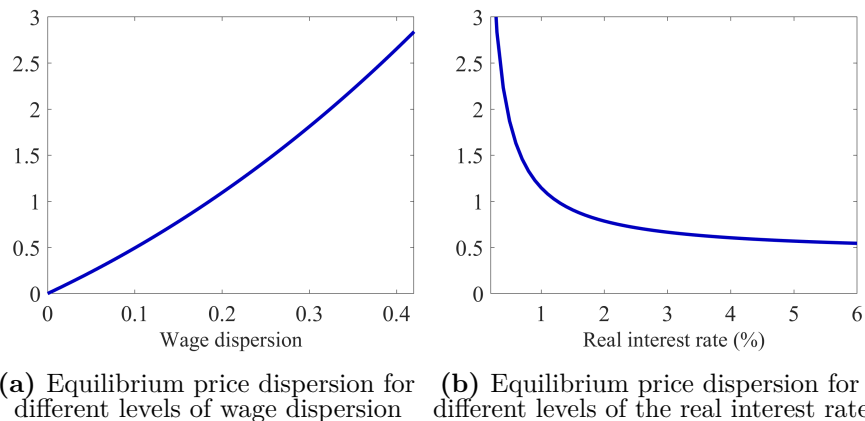


Figure 3.2: Equilibrium price dispersion

Note: Figure 3.2a shows the equilibrium house price dispersion implied by the model at different levels of wage dispersion ω . Figure 3.2b shows the equilibrium house price dispersion implied by the model at different levels of the real interest rate r .

The graphs show how more dispersed wages and a lower real rate drive up house price dispersion. Importantly, the effect is quantitatively significant both for wages and the interest rate. This gives good reason to believe that both these variables are important drivers of house price dispersion and can potentially explain the divergence since 1995.

3.3.3 What have we learned?

This very simple model aids us in understanding how wages and the interest rate interact with local house prices. It highlights that house prices act as a compensating differential. When one region becomes more attractive, prices adjust to ensure that no region is superior to the other. Both increased wage dispersion and a lower real interest rate

makes the already expensive region more attractive. Increased wage dispersion does so for obvious reasons. The lower interest rates works through differential land rents. However, the quantitative implications of the model are stark, arguably because the model lacks several elements that are important for the question at hand.

First, the model lacks dynamics. The representative household solves a static problem, meaning that there is no savings decision. Therefore the user cost of housing had to be assumed rather than derived, and the role of housing as a savings vehicle completely ignored. Dynamics not only provides us with micro-founded savings behaviour over the life-cycle, but also allows us to study changes over time. As the purpose of this paper is to explain the path of house prices over a 23-year period, this element is not just important but absolutely necessary. Second, the model does not model actual ownership. To capture the role of housing as a savings vehicle, houses need to be modelled as a separate asset class. By doing so, we can also account for the fact that housing is a highly illiquid asset by introducing transactions costs and idiosyncratic income risk. Since the consumption of housing is tied to living in the region where the house is located, these transaction costs also operate as a moving cost for homeowners. Third, the financing of housing needs to be addressed. In reality, a lot of the housing is not financed by equity but rather by mortgages, which are associated with occasionally binding borrowing constraints and repayment plans. As highlighted by Boar et al. (2020) and in chapter 2 of this thesis, these constraints are binding for many households and thus comprise an important component of the user cost of housing. Last, but certainly not least, we need to model housing supply. So far, everything that has been discussed has been related to the demand side of the housing market.

For these reasons, the remainder of this paper will focus on building, calibrating, and running policy experiments in a much richer framework that addresses all of the above concerns.

3.4 Model

To analyze the impact of wages, the interest rate, and supply-side restrictions on house prices, I construct a life-cycle model with overlapping generations, heterogeneous agents, and incomplete markets. The model is in discrete time, with one model period corresponding to one year. It features four types of agents: households, rental firms, a production sector, and a government.

Households are born with different initial earnings levels w , with further heterogeneity arising from idiosyncratic income shocks. The model has two regions $q \in \{q^l, q^h\}$, and households choose to live in one of them. Rental firms operate on a competitive market with free entry and exit, and produce rental services sold to households who do not own their dwelling. The production of consumption goods is done by competitive firms, using a CRS production technology with labor as its only input. The government acts as a tax and transfer system, and decides on land-use regulation.

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 buying and selling a house. The housing stock is region specific and households can only consume and own housing in their region of residence. In equilibrium, house- and rental prices adjust to clear the housing market in each region. The interest rates on bonds and mortgages are exogenous, and both assets are supplied elastically.

3.4.1 Households

Every household starts life by deciding in which region q to live, after which it draws its initial wage level. Earnings consist of a permanent part p , the logarithm of which evolves following a random walk with a trend, and a transitory shock v drawn from a log-normal distribution. Households retire with certainty after period J_{ret} and cannot live

past period J . After J_{ret} , households earn a constant fraction R of the permanent part of their wage in period J_{ret} from the social security system. Between any two periods j and $j + 1$, each household survives with an age-dependent probability ϕ_j and discounts the future exponentially with a discount factor β . In each period, households derive utility from the consumption of a generic consumption good c and housing services s . The utility function is a CRRA function with a Cobb-Douglas aggregator over c and s ,

$$U(c, s, q, q') = \frac{(c^\alpha s^{1-\alpha})^{1-\sigma}}{1-\sigma} + \psi(q) - \zeta^M \mathbb{I}^M, \quad (3.4)$$

where the second term captures differences in amenity values across space. The last term adds a utility cost of moving ζ^M , which is multiplied by an indicator variable for the chosen location q' being different from the location the household currently resides in q . The household also has a warm-glow bequest motive given by

$$U^B(B) = \Theta \frac{B^{1-\sigma}}{1-\sigma}, \quad (3.5)$$

where B is the net worth of the household and Θ is a parameter determining the weight assigned to the utility from leaving bequests.

A household enters each period j with a location q , some bonds b , housing h , and mortgage m . The household then draws a permanent and a transitory earnings shock, which determine a new earnings level w , and it pays taxes Γ . It also draws a taste shock $\varepsilon(q')$ for each region from an extreme value distribution with parameter σ_ε . The household then chooses consumption c , housing services s , bonds b' , mortgage m' , house h' , and location q' . Housing services are either obtained by owning a house or through renting. Each unit of housing costs $p_h(q)$ to buy and $p_r(q)$ to rent. Owned housing produces housing services through a linear technology $s = h'$, also meaning that households cannot be landlords and those who rent cannot own

a house. Households can use mortgages m' to finance homeownership, but this come with an interest rate of $r^m > r$. Bonds can only be purchased in non-negative amounts and pay an interest rate r .

Having a mortgage comes with three constraints: a loan-to-value (LTV) requirement, a payment-to-income (PTI) requirement, and a pre-specified repayment plan. The LTV and PTI requirements apply whenever the household takes up a new mortgage, either by buying a new house or refinancing an exisiting mortgage. The LTV limit specifies that households can only finance up to an exogenous share $1 - \theta$ of the house value using mortgages

$$m' \leq (1 - \theta)p_h(q)h'. \quad (3.6)$$

The LTV requirement ensures that homeownership is lower among younger households. In order to become a homeowner, a household has to accumulate enough bonds to afford the down payment. The PTI requirement dictates the maximum amount of mortgages that a household can take up, based on its current income. It states that the amount of payments associated with the house and the mortgage cannot exceed a fraction ψ of the household's income. Formally,

$$\chi_{j+1}m' + (\tau^h + \varsigma^I)p_h(q')h' \leq \psi \frac{w}{v}, \quad (3.7)$$

where χ_{j+1} is the required amortization, τ^h is a proportional property tax, ς^I is an insurance cost, and w/v is earnings net of the transitory income shock.³⁴The repayment plan, or amortization requirement, is modelled to mimic a standard 30-year annuity mortgage contract. In

³These are the main components used by actors in the mortgage market to assess the household's payment capabilities. The home insurance payment is only included in the PTI requirement for calibration purposes, and does not enter the model elsewhere

⁴See section 3.4.2 for a description of the various components of household earnings.

each period, the homeowner needs to make a minimum payment on its mortgage χ_j , where

$$\chi_j = \left(\sum_{k=1}^{M_j} \left[\frac{1}{(1+r_m)^k} \right] \right)^{-1}. \quad (3.8)$$

I set $M_j = \min\{30, J - j\}$ to ensure that if the household has less than 30 years until it dies with certainty, this is the end date of the contract. Furthermore, I allow for the use of cash-out refinancing of existing mortgages. This means that the homeowner can pay off less than the amount stipulated above, but doing so comes at a cost ζ^r and requires that the household meets the LTV and PTI requirements.

The household problem has six state variables: age j , permanent earnings p , location q , house size h , mortgages m , and cash-on-hand x . Age evolves deterministically and the permanent earnings component follows an autoregressive process. The remaining four states are either directly determined by the household, or affected by the household's choices. The cash-on-hand state is defined as

$$x \equiv w + (1+r)b - (1+r^m)m + (1-\zeta^s)p_h(q)h - \delta^h h - \Gamma, \quad (3.9)$$

where $(1-\zeta^s)p_h(q)h$ is the value of the house net of the transaction cost of selling ζ^s . The maintenance cost δ^h is paid by all homeowners, and assumed to be independent of region and prices. The last term Γ is the sum of total tax payments, and is given by

$$\Gamma \equiv \mathbb{I}^w \tau^{ss} w + \tau^c r b + \tau^h p_h(q) h + (1-\lambda)(w - r^m m - \tau^h p_h(q) h). \quad (3.10)$$

Households pay a social security tax during working age (indicated with the binary variable \mathbb{I}^w) equaling a share τ^{ss} of earnings, a tax on capital income with tax rate τ^c , and a proportional income tax

controlled by the parameter λ . This latter tax includes the mortgage interest- and property tax deductibility.

The household problem includes a discrete choice of how to consume housing services. The household can either rent their home, buy a new house, stay in the same house it entered the period with but refinancing the mortgage, or stay in the same house and following the repayment plan. I will let the indicators $\mathbb{I}^R, \mathbb{I}^B, \mathbb{I}^{Ref}, \mathbb{I}^S$ distinguish between renting, buying, refinancing, and staying. The household problem can then be written as follows:

$$\begin{aligned}
 V_j(m, h, x, p, q) &= \max_{c, s, h', m', b', q'} \\
 &U_j(c, s, q, q') + \beta \mathbb{E} [\phi_j V_{j+1}(m', h', x', p', q') + (1 - \phi_j) U^B(B')] + \varepsilon(q') \\
 &s.t. \\
 &c + b' + \mathbb{I}^R p_r(q) s + (\mathbb{I}^B (1 + \zeta^b) h' + \mathbb{I}^{S, Ref} (1 - \zeta^s) h) p_h(q) + \mathbb{I}^{Ref} \zeta^r \leq x + m' \\
 &x' = w' + (1 + r) b' - (1 + r^m) m' + (1 - \zeta^s) p_h(q) h' - \delta^h h' - \Gamma' \\
 &0 \leq m' \leq (1 - \theta) p_h(q) h' \\
 &\mathbb{I}^{B, RF} \left(\frac{\chi_{j+1} m' + (\tau^h + \tau^I) p_h(q) h'}{w/v} \right) \leq \psi \\
 &\mathbb{I}^S m' \leq (1 + r^m - \chi_j) m \\
 &s = h' \quad \text{if } h' > 0 \\
 &q' = q \quad \text{if } j > J_{ret} \\
 &c > 0, s \in S, h' \in H, b' \geq 0, q' \in \{q^l, q^h\}.
 \end{aligned}$$

The problem is characterized by the Bellman equation, the budget constraint, the law of motion for cash-on-hand, and a number of constraints. The sets of housing, S for rentals and H for owner occupied, consist of discrete sizes and H is a proper subset of S . Specifically, the smallest house size \underline{h} in H is larger than the smallest available size

in S . Above and including that bound, the sets are identical.⁵ I also impose that the household cannot move after retirement, motivated by the low migration rates in the data for this age group (Molloy et al., 2011).

3.4.2 The income process

The underlying driver of all household behavior is the income process. I am going to follow convention and let household earnings be generated by an AR1-process with full persistence. Similar to Cocco et al. (2005), I will estimate a deterministic life-cycle profile of earnings and let earnings risk be generated by permanent and transitory shocks. For a given household i at age $j \leq J^{ret}$ in location q , the logarithm of earnings is the sum of five components: an individual-fixed component ω_i , an age-fixed component g_j , a permanent component n_{ij} , a transitory component v_{ij} , and a state-fixed component $\log(w(q))$

$$\log(w_{ij}) = \omega_i + g(j) + n_{ij} + v_{ij} + \log(w(q)). \quad (3.11)$$

The term g_j captures the hump-shaped life-cycle profile of earnings present in the data. The term $\log(w(q))$ captures the difference in the marginal product of labor across locations, and is further discussed in section 3.4.4. The remaining components differ between households of the same age and location. The term ω_i is a household fixed-effect, which is needed to capture the initial dispersion in earnings and is assumed to be distributed $N(0, \sigma_\omega^2)$. The terms n_{ij} and v_{ij} model idiosyncratic earnings risk. The latter is an i.i.d. transitory shock with distribution $N(0, \sigma_v^2)$. The former is a random walk that allows

⁵The assumption of a smallest owned house size is also assumed in e.g. Gervais (2002), Floetotto et al. (2016), Sommer et al. (2013), and Sommer and Sullivan (2018). The introduction of this constraint leads to less ownership among low income households, which is consistent with data.

households to permanently deviate from the deterministic trend

$$n_{i,j} = n_{i,j-1} + \eta_{ij}, \quad (3.12)$$

where η_{ij} is a permanent earnings shock distributed $N(0, \sigma_\eta^2)$. When solving the household problem outlined in section 3.4.1, the permanent earnings component that enters as a state in the Bellman equation is the sum of first three terms

$$p_{ij} = \exp(\omega_i + g_j + n_{ij}). \quad (3.13)$$

During retirement, the household simply receives earnings from the social security system equal to a fraction R of the permanent earnings in the last period before retirement. This means there is no idiosyncratic income risk when $j > J^{ret}$.

3.4.3 The rental market

The rental price p_r is determined in a competitive market. It consists of a unit mass of homogeneous firms who have two investment options. They can either buy housing on the same market as the households and rent it out on a period-by-period basis, or invest in risk-free bonds with a return set by the world market. The present value of after tax profits for firm f investing in h_f units of rental property in region q is

$$\pi_f^{rent} = (1 - \tau^c) \left(p_r(q) h_f - \frac{1}{1 + \tilde{r}} [\delta_r + \tau^h p_h(q)' + \Delta p_h(q)] h_f \right).$$

The firm's revenue is simply the rental income $p_r(q) h_f$. It then deducts its operating expenses from these before paying taxes on the remaining return. These operating expenses consist of three parts: the maintenance cost δ_r , the property tax $\tau^h p_h(q)$, and any negative price return $\Delta p_h(q) \equiv p_h(q) - p_h(q)'$ that occurs between the two periods in which the house is rented out. All these expenses are discounted at

the net return on bonds $\tilde{r} \equiv (1 - \tau^c)r$ as they are realized next period.

If the firm instead invests in risk-free bonds, the present value is given by

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

Imposing a free entry and exit condition, the return to both alternatives must be the same such that $\pi_f^{rent} = \pi_f^{bonds}$. This yields an equilibrium rental price of

$$p_r(q) = \frac{1}{1 + \tilde{r}} (\delta_r + r p_h(q) + \tau^h p_h(q) + \Delta p_h(q)). \quad (3.14)$$

In the steady state $\Delta p_h(q) = 0$, which returns the formula for the user cost in section 3.3 with the addition of a property tax. Although very simple, this formula captures the idea of rental housing as just another form of investment. If interest rates fall, then rents have to fall as well in order for returns to be equal. A critique of this formulation is that a majority of rental housing is supplied by households, rather than firms, which could imply that capital is not freely mobile between the rental market and other forms of investment. With this motivation, Sommer et al. (2013) let households own rental property directly. However, as long as there is some marginal investor who is willing to invest in both markets, the relationship between rents and the interest rate has to be determined by a condition stating equal return on all assets, similar to the one outlined above. Moreover, the specification here gives a closed form solution for the rent as a function of the interest rate and house price. This means there is no need to introduce the rent as an extra equilibrium object to be searched for in an already computationally heavy model.

3.4.4 Production

There are two goods produced in the economy: a tradeable generic consumption good c and housing h . The numeraire good c is produced competitively by firms using labor as input in a constant-returns-to-scale production function. Productivity differs between regions, implying different wages across space. Firms choose labor L to solve the problem

$$\max_L Z(q)L - w(q)L,$$

where $Z(q)$ is the productivity of labor in region q . The competitive setting ensures that wages equal marginal product

$$w(q) = Z(q) \tag{3.15}$$

3.4.5 Construction

Housing is produced using a Leontief production function with structures and land as inputs. The structures are produced using the numeraire good c as its only input. The land is assumed to be owned by the government, who also decides on the quantity of land that is available for construction. The construction sector problem is given by

$$\max_{c, \hat{L}} p_h(q) \min\{Z_h c, \hat{L}\} - c - p_l(q)\hat{L},$$

where $Z_h c$ is the amount of structures and \hat{L} is the amount of land. I assume that the government sells the land at a competitive price. This means that the construction sector makes zero profits, and that all the differences in house prices across locations is made up of land rents.

The problem has two possible solutions. One possibility is that

land is abundant. In that case, the house price equals the marginal cost of producing new houses and the housing supply is completely elastic. Another possibility is that land is scarce. This means that land prices are positive, and that the government is in full control of the size of the housing stock as they control the supply of land. I will assume that this is the case. In particular, I assume the government sets housing supply $\bar{H}(q)$ as an isoelastic function⁶

$$\bar{H}(q) = \Upsilon_h p_h(q)^{E_h(q)}. \quad (3.16)$$

In the steady state equilibrium, house prices are constant and therefore the housing stock in each region is fixed. This also implies that the government does not sell any land in equilibrium.

3.4.6 The government

The government plays a limited role in this paper, and only acts as a tax and transfer system. As outlined in 3.4.1 and 3.4.3, it collects taxes from households and rental firms. There are no local governments acting to tax agents differently across space. Total tax revenue for the government is

$$TR = \sum_{j=1}^J \Pi_j \int_0^1 \Gamma_{ij} di + \int_0^1 \tau^c r p_h(q) h_f df, \quad (3.17)$$

where i indexes households, f indexes firms, Π_j is the exogenous distribution of households over age, and Γ is total taxes as described in equation (3.10). I assume both rental firms and households to

⁶Although very reduced form, this setting is the same as in Kaplan et al. (2020) and Favilukis et al. (2017), with the exception that I distinguish between the maintenance of existing structures and construction of new houses. Both these papers let housing supply be determined by an exogenous supply of land decided on by the government, and a single parameter that determines the housing supply elasticity.

be of unit measure. To simplify matters, I also let the government collect all the bequests left behind by the households who die. After the assets have been collected, the government earns interest on the bonds, sells the houses and incurs the transaction costs, and repays any outstanding debt including interest. The net amount collected is

$$BQ = \sum_{j=1}^J \Pi_j (1 - \phi_j) \int_0^1 ((1 + r)b'_{ij} + (1 - \zeta^s)p_h(q)'h'_{ij} - (1 + r^m)m'_{ij}) di. \quad (3.18)$$

Letting the government collect the bequests is just a convenient way of making sure the model is closed. The government runs a balanced budget

$$TR + BQ = \sum_{j=J_{ret}+1}^J \Pi_j \int_0^1 Rp_{i,J_{ret}} di + G. \quad (3.19)$$

Part of the expenditures is financing the social security system. I follow convention and let all households receive a fraction R of their permanent earnings in the last period of working life as income in all periods of retirement. The rest of the government's revenues are spent on wasteful government spending G .⁷

3.4.7 A discussion of model assumptions

Before going into the calibration of all the parameters, it good to take a step back to discuss two key features of the model. The first is migration. Why do people move in the model? And how can the moving patterns be aligned with the data? The second feature is the maintenance cost of housing being independent of prices. This was the key assumption in section 3.3, and is built into the full model as

⁷The share of government spending of GDP remains roughly constant in all the policy experiments, as the bulk of taxation is linear in income and hence GDP.

well. Therefore, a closer investigation of whether this assumption is supported by the data is warranted.

Migration in equilibrium

A full equilibrium definition is provided in the appendix. For now, note that the solution revolves around two conditions

1. Housing markets need to clear:

$$\sum_{i=1}^J \Pi_j \int_0^1 s_{ij}(q) di = \bar{H}(q) \forall q$$

2. The marginal household i_m needs to be indifferent between the two regions:

$$\mathbb{E}\{V_{imj}(q^l)\} = \mathbb{E}\{V_{imj}(q^h)\}$$

The first condition is merely a condition saying that the house price, the object of interest in this paper, is set by the intersection of demand and supply in the housing market. However, the demand for housing in region q is not just a function of the price $p_h(q)$. It also depends on how many households live in that region. The second condition disciplines the spatial dimension by saying that the expected value of residing in each region has to be the same for some household. By not imposing any restriction on where households of age $j = 1$ reside, this marginal household will be of the youngest cohort. There is no technical reason why this has to be true. It would also be possible that all newborn households find one region to be superior to the other, and therefore locate themselves in the same region initially. However, such an equilibrium is not realistic. The calibration of the model will ensure that the demographic composition of each region matches the data in the initial steady state equilibrium. This implies

that there are newborns in both regions, which necessitates that the expected value of each region is the same. When conducting policy experiments, the solution will also be characterized by this condition. However, that is an outcome of the model rather than an assumption.

The assumption that households can decide freely on their location q in the first period of life is motivated by the data on migration. Molloy et al. (2011) show that the annual interstate migration rate for people aged 18-24 was 5.1% in the period 1980-1990. As only 60-70 % of the cross-MSA migration rate also crosses state borders, this suggests an annual cross-MSA migration of roughly 7.5 %. In other words, a significant share of young adults move between labor markets in their first six years of adulthood. Since the first age in my model represents the age 23, letting households choose their initial location freely is intended to capture these flows.

Migration over the rest of the life-cycle happens for two reasons. The first is simply random migration in both directions due to the preference shock ε , which is extreme value distributed of type one. This i.i.d. shock ensures that households move in both directions at every point in the life-cycle. The second reason for migration is the life-cycle aspect. Early in life, there is an incentive to live in the high-productive region q^h . The reason is that the household is a net saver, who wants to accumulate wealth both for retirement and for bequest reasons. When the household approaches retirement, it wants to move to the low productive region q^l , as the more affordable housing in q^l makes it the superior location of residence for all households. In reality, we do not see everyone moving out of New York City to the rural parts of West Virginia at retirement. For this reason, I introduced a cost of moving into the utility function. By calibrating the size of this cost properly, I can make sure that the demographic composition of the model's regions matches the data.

Are maintenance costs and prices independent?

In section 3.4.5, I assumed that the housing structure is produced using a linear function of the numeraire good c . It implied that building new houses has the same cost in both regions, and is independent of the house price. This model feature is motivated by recent evidence looking at detailed data on construction costs. For the U.S., Glaeser and Gyourko (2018) show that the marginal cost of constructing a new house is roughly constant across space, differing by approximately 20 % between the most expensive and the cheapest MSA. Furthermore, they show that there is no time-trend in these costs. Building a house today costs the same as it did in the 1980's.⁸ For this reason, the parameter Z_h that determines how effective the construction sector is in converting the generic consumption good to a structure is assumed to be constant across space and time.

This also suggests that the maintenance cost of existing structures is constant and thereby independent of any price changes. As highlighted in section 3.3, this is important for the interest rate to affect the user cost differentially across MSAs. To check this assumption, I use data from the American Housing Survey (AHS) and compare self-reported maintenance expenditure over time between MSAs.

For each region, I calculate the median expenditure on maintenance and the median house value in 2001. I then repeat this exercise for 2005 and see if there is any significant correlation between the changes in house prices and maintenance spending. A simple OLS regression shows little correlation with a p-value of 0.508. The reason for studying a 4-year period is that any endogenous response of the quality and composition of the housing stock to whatever is driving price changes is likely to be controlled for, as construction of new housing is slow. Furthermore, the period of 2001-2005 saw large increases in prices which were very dispersed across locations. I therefore think this

⁸This finding holds true for other countries as well. See Knoll et al. (2014).

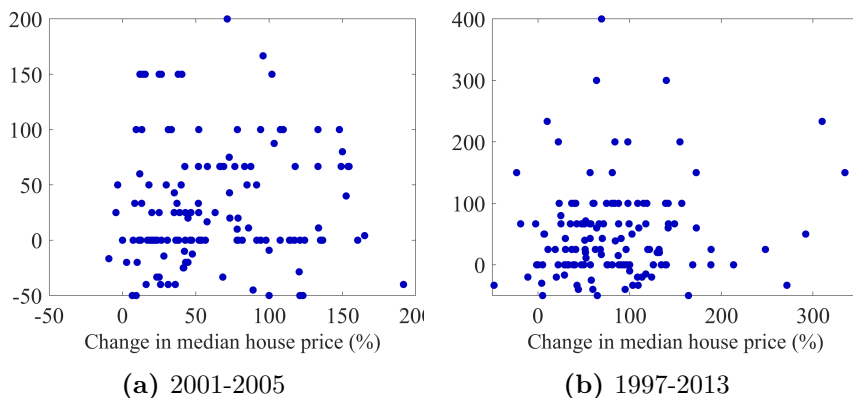


Figure 3.3: Percentage changes in median housing maintenance expenditures and house prices by MSA.

Note: Figure 3.3a plots changes over the period 2001-2005. Figure 3.3b plots changes for the period 1997-2013. All data is from the American Housing Survey and uses nominal prices

period has the largest potential when it comes to detecting any direct effect of prices on maintenance costs. As a robustness check I conduct the same exercise for the years 1997 and 2013, which roughly captures the time period of interest in this paper.⁹ This yields a small negative correlation with a p-value of 0.6. The results are illustrated using scatter plots in figure 3.3. In short, I find no support for prices directly affecting maintenance expenditures.

3.5 Calibration

The model comes with a large number of parameters to be calibrated. Some are calibrated directly from data or previous studies, while other are calibrated by matching moments generated by the model

⁹The AHS was redesigned in 1997 and then again in 2015. Therefore any comparison between years outside this interval is not feasible

to the data. More details on the calibration process are given in the appendix.

3.5.1 Exogenously calibrated parameters

Prices and housing supply. As I want to explain why house prices have changed differently across space, which was illustrated using data for 383 MSAs in figure 3.1b, I need to map each MSA in the data into the two model regions. I do this mapping based on the observed change in house prices. Using the median house price for each MSA in the 2005 wave of the ACS combined with the FMHPI for each location, I am able to calculate the change in the median house price between 1995 and 2018 for all locations. I define region q^h to represent all MSAs with a house price increase above the median, and let the remaining locations make up q^l . Using the same data, I can also calibrate the initial house prices $(p_h(q^l), p_h(q^h))$ as the population weighted average price in each group of MSAs in 1995.¹⁰ For convenience, I normalize $p_h(q^h) = 1$. The housing supply elasticities are calibrated by combining the estimates of Saiz (2010) with readily available population data from the Census Bureau. $E_h(q)$ is calibrated to the weighted average of housing supply elasticities in each group of MSAs. Given the initial prices, I can back out Υ_h in equation (3.16), as it is the only remaining element of that equation.

The income process. To calibrate household income, equations (3.11) and (3.12) need to be estimated. First, I pin down the shock variances $(\sigma_\omega^2, \sigma_\eta^2, \sigma_v^2)$ and estimate the deterministic trend g_j using micro data. For this purpose, I use data from the PSID for years 1970 to 1992. First, g_j is estimated by running a regression of the logarithm of household earnings on a set of age dummies. A third

¹⁰The price difference across space might reflect differences in housing characteristics, which I would ideally like to control for. However, data from the American Housing Survey suggests that this is not a huge issue. See the appendix for more details.

order polynomial is then fitted to the series of age dummies, giving me an estimate for g_j . The variances σ_η^2 and σ_v^2 are estimated as in Carroll and Samwick (1997). The remaining parameter σ_ω^2 can then be backed out as the variance of earnings for the youngest age group that is not accounted for by the other two idiosyncratic shocks. The resulting parameter values are listed in table 3.1. Since the PSID does not contain data on region of residence, I use the data from the 1990 census to calibrate wage differences across space. I use observations for individuals aged 23-60 with positive earnings, and divide them into two groups based on MSA of residence. I then use the weighted average in each group to calibrate $w(q)$ in equation (3.11). For convenience, I normalize this parameter for those in the high-priced region q^h to one.

Demographics and preferences. The household starts life at age 23. The probability of dying between any two periods is calibrated using the projected and observed mortality rates of men born in 1950 from “Life Tables for the US social security area 1900-2001” from Bell and Miller (2005). The retirement age is set to 65 and all households die with certainty at age 83. The parameter for relative risk aversion, σ , is set to 2 which is a standard value used in the literature. The preference parameter α is set to 0.68, as in Hsieh and Moretti (2019).

Tax system. The payroll tax τ^{ss} is set to 0.153. In the U.S. this tax is levied equally on worker and firm, but as the production sector is competitive, I can let the full tax burden fall on the households without loss of generality. The parameter λ is set to 0.87 to match the average marginal federal income tax rate of 13%, a target taken from Harris (2005). Since capital income is often treated the same as labor income in the U.S. tax code, I calibrate the tax rate on capital income τ^c to 13% as well. The property tax τ^h is set to 0.01, which is the average property tax rate in the American Housing Survey. The common replacement rate from the social security system is set to $R = 0.5$ as in Díaz and Luengo-Prado (2008).

Financial markets. The interest rate is estimated from market

yields on 30-year constant maturity treasury securities for years 1985-1995, which are then deflated using the year-to-year changes in CPI. This yields an interest rate of just under 4%, which motivates a calibration of $r = 0.04$. The spread between the real rate on bonds and the real rate on mortgages $\kappa = r^m - r$ is calibrated as the average difference between the yield on 30-year constant maturity treasury securities and the average rate on a 30-year fixed rate mortgage. Data for the latter is available from Freddie Mac's primary mortgage market survey. Calibrating κ as the average difference for the years 1985-1995 gives $\kappa = 0.014$. Data from the U.S. Census Bureau (U.S. Bureau of the Census, Statistical Abstract of the United States (GPO), 1987, 1988, 1994) lists the average down-payment for first-time home buyers as between 11.4 and 20.5 percent. However, data from the SCF shows a significant number of households with less equity than this. Therefore, I set the model's downpayment requirement $\theta = 0.1$, a value commonly used in the literature. The payment-to-income requirement ψ is set to 0.28, as in Greenwald (2018).

Housing costs. The depreciation rate of owned housing δ^h is set to 0.0135. This is the same as Kaplan et al. (2020) who set the depreciation rate to 1.5% of the housing value, a number they take directly from the Bureau of Economic Analysis tables on consumption of fixed housing capital in 1997. With around half of the housing stock located in each region in my model, $\delta^h = 0.0135$ is a suitable calibration to match this estimate. The transaction costs to buying and selling are taken directly from Gruber and Martin (2003) who estimate these costs to 2.5% and 7% of the house value.

3.5.2 Estimated parameters

Six parameters remain to be calibrated. This is done by matching moments generated by the model to the data. The maintenance cost of rental housing δ^r operates as a wedge between how favorable owned

housing is vis-à-vis renting. As such it affects how quickly agents will become homeowners, and is therefore used to target the homeownership rate for households under the age of 30. The minimum house size \underline{h} operates as a barrier to owning for low income households who desire a housing expenditure below that implied by this parameter. Consequently I use this parameter to calibrate the overall homeownership rate in the economy. The discount factor β affects the households' desire to save and borrow, and is therefore targeted at the median loan-to-value ratio. The parameter Θ in the utility function for bequests is targeted against the savings behavior of older agents. Specifically, it is targeted at the ratio of net worth at age 75 to net worth at age 50, which is an indicator of the importance of bequests as a motive for saving.

The last two parameters, σ_ε and ζ^M , are chosen to capture migration patterns. This task is complicated by the lack of good migration data, especially since I am interested in migration across two sets of MSAs which I have classified myself. Molloy et al. (2011) go through the available data on migration in the United States and back out the gross migration rates across MSAs. Around 11.4% of the population moved between MSAs over the five-year period of 1995 to 2000. Assuming a yearly moving probability that is homogeneous across households, this implies an annual gross migration rate of 2.39%. As I am interested in migration between two sets of MSAs of roughly the same size, I choose to target the variance of the extreme value shocks to generate a gross migration rate of 1.2% per year.

The parameter ζ^M also affects the gross migration coming from these taste shocks, but it also impacts the willingness to move for other reasons. In the model, there is an underlying desire among households to live in q^h early on to accumulate wealth and move to q^l later in life to enjoy the low cost of living during retirement. Therefore ζ^M is calibrated to match life-time migration. Using data from the 1990 census, I calculate the ratio of the number of agents aged 23-31 to the

number of agents aged 56-64 in each set of regions. I then use the ratio of these ratios as my target for this parameter, as it is informative of the relative demographic composition. The data yields a target of 1.36, meaning that the ratio of young to old workers is 36% higher in q^h than in q^l .

3.5.3 Model fit

The calibration is summarized in tables 3.1 and 3.2, in the latter case joint with the moments in the data. The tables suggest a decent fit overall.

Parameter	Description	Value
σ	Coefficient of relative risk aversion	2
α	Preference weight on numeraire good	0.68
τ^c	Capital gains tax	0.13
λ	Income tax	0.87
τ^{ss}	Payroll tax	0.153
τ^h	Property tax	0.01
r	Interest rate	0.04
κ	Yearly spread, mortgages	0.014
θ	Downpayment requirement	0.10
ψ	Payment-to-income requirement	0.28
δ^h	Depreciation, housing	0.0135
ζ^b	Transaction cost if buying house	0.025
ζ^s	Transaction cost if selling house	0.07
R	Replacement rate retirees	0.50
σ_v^2	Var. transitory income shock	0.061
σ_η^2	Var. permanent income shock	0.012
σ_α^2	Var. Household fixed income component	0.156
$p_h(q)$	House prices	[1,0.792]
$Z(q)$	Labor productivity	[1,0.893]
$L(q)$	Share of households by region	[0.515,0.485]
$E_h(q)$	Housing supply elasticity parameter	[1.45,1.67]

Table 3.1: Exogenously calibrated parameters

Note: Parameter values are calibrated directly to data or taken from previous studies. For parameters that are region specific, the first number refers to $q = q^h$.

Parameter	Description	Value	Target moment	Data	Model
δ^r	Maintenance cost, rentals	0.059	Homeownership rate, age ≤ 30	0.399	0.405
\underline{h}	Minimum owned housing size	160	Homeownership rate	0.684	0.713
Θ	Utility level of bequests	0.4	Ratio of avg. net worth, age 75 vs. 50	1.681	1.773
β	Discount factor	0.955	Median loan-to-value ratio	0.313	0.313
σ_ε	Moving shock parameter	0.247	Gross migration rate	0.011	0.007
ζ^M	Moving cost	0.27	Relative ratio of old vs. young workers	1.360	1.403

Table 3.2: Endogenously calibrated parameters

Note: The third column shows the parameter values used. Column four lists the moments used to calibrate the parameter. The last two columns shows the moment value in the data and the model.

3.6 Results

This section presents the results from running a set of policy experiments. I start by comparing steady state equilibria for different combinations of changes to house price fundamentals. Doing so ignores the role of dynamics, but provides a prediction for where the economy is heading and puts numbers on the relative contributions of the house price fundamentals for house prices. I also conduct an experiment where I turn off the option for households to migrate, in order to decompose the intensive and extensive margin effect that changes in fundamentals have on house prices. I then proceed by investigating the role of dynamics by solving for the transition path between two steady states. The section ends with quantifying the welfare gains for the different households over the transition path.

3.6.1 The role of housing demand

The real interest rate

To see how the real interest rate affects house prices, I take the change in the real rate as exogenously given. I calibrate the new value in the same manner as in section 3.5, but using more recent data on nominal bond rates and CPI inflation. This procedure reveals that the real rate reached zero in August of 2018 and has since fluctuated around

that level. For this reason, I set $r = 0$.¹¹

Table 3.3 presents the results from solving the model with the lower interest rate. The first row displays the values from the initial steady state, which by construction matches the data for the early 90's. The second row presents the corresponding values in the data for 2018, while the third row shows the same statistics generated by the model. The last row displays the absolute difference between the second and the third row, i.e. how far the model is from replicating the data.

	Prices		Pop. share		Wages	
	q^h	q^l	q^h	q^l	q^h	q^l
<i>Baseline</i>	1.000	0.792	0.515	0.485	1.000	0.893
<i>Data</i>	1.586	0.824	0.552	0.448	1.248	1.030
<i>Model</i>	1.158	0.829	0.572	0.428	1.000	0.893
<i>Difference</i>	-0.428	0.005	0.020	-0.020	-0.248	-0.137

Table 3.3: Results: Changed real interest rate

Note: The values correspond to those in the initial steady state, the data, and the model with the changed interest rate respectively. The bottom row shows the absolute difference in each column between the second and third row. Wages are the region-specific wage components $w(q)$.

When the interest rate decreases, the user cost of housing falls. This leads to housing demand increasing in both regions which require higher house prices to clear the market. Moreover, the fall in the user cost is larger in the productive region where prices are already high and thus more tied to the opportunity cost of housing equity and mortgage interest payments. This suggests that prices should increase more in q^h than in q^l . At the same time, the differential fall in the user cost triggers an extensive margin response. With the user cost falling more in the productive region, there is an incentive for households to

¹¹Repeating the experiments in this section with a slightly higher rate does not alter the overall conclusions.

locate there. An increase in the dispersion of house prices is required to ensure that both housing markets clear.

The results corroborate this line of reasoning. Prices increase in both regions, prices become more dispersed, and more households move to the productive region. For the low-productive region, the price level is virtually unchanged, and thus the magnitude of the price change is fairly close to the data. For the high-productive region however, the price increase is only about 30% of what we see in the data. Overall this means that the interest rate alone is unable to explain the increase in both the average house price and the inter-regional house price dispersion. In terms of location choices, the model overshoots a bit compared to the data. The share of people living in the productive region increases by two percentage points more than in the ACS.

Wages

To see the effect of wages on house prices, I change the two labor productivity parameters $Z(q)$. To do this, I repeat the exercise conducted when calibrating them in section 3.5, but using the recent ACS data rather than the 1990 census. Table 3.4 presents the results from solving the model for these new values of $Z(q)$.

As seen in the last two columns of table 3.4, wages go up in both regions. All else equal this drives up housing demand and prices across the board. As wages go up more in the expensive region we should also see an increase in the dispersion of prices. This divergence of prices comes both from residents of q^h increasing their demand of housing more than the households in q^l , and from a flow of workers from the low to the high-productive region in pursuit of higher wages.

Quantitatively, prices change a bit more than what we saw when the real interest rate was changed. The house price is fairly stable in the low-productive region, whereas the increase in the high-productive

	Prices		Pop. share		Wages	
	q^h	q^l	q^h	q^l	q^h	q^l
<i>Baseline</i>	1.000	0.792	0.515	0.485	1.000	0.893
<i>Data</i>	1.586	0.824	0.552	0.448	1.248	1.030
<i>Model</i>	1.271	0.760	0.626	0.374	1.248	1.030
<i>Difference</i>	-0.315	-0.064	0.074	-0.074	0	0

Table 3.4: Results: Changed labor productivities

Note: The values correspond to those in the initial steady state, the data, and the model with the changed productivity parameter values respectively. The bottom row shows the absolute difference in each column between the second and third row. Wages are the region-specific wage components $w(q)$.

region is almost half of what we see in the data. The model generates a much larger change in the location choices than the data. This in turn explains why the model can generate such a significant amount of price dispersion, despite the change in wages not varying that much across locations. This extensive margin response even makes prices go down in q^l , despite wages and hence housing demand per household going up.

Combining wages and the real rate

The main policy experiment in this paper is to see if the increase in wages together with the fall in the real interest rate can jointly explain both the divergence and the overall increase of house prices. To see this, I conduct an experiment where I feed in both the changes in productivity and the lower real rate into the model and solve for the steady state equilibrium. The results of this exercise are listed in table 3.5.

Regarding prices, the model is able to explain most of the observed changes between 1995 and 2018. The price in the low-productive region is almost unchanged, both in the model and the data. For the high-productive region, the model is still not quite able to explain the

	Prices		Pop. share		Wages	
	q^h	q^l	q^h	q^l	q^h	q^l
<i>Baseline</i>	1.000	0.792	0.515	0.485	1.000	0.893
<i>Data</i>	1.586	0.824	0.552	0.448	1.248	1.030
<i>Model</i>	1.414	0.772	0.678	0.322	1.248	1.030
<i>Difference</i>	-0.172	-0.052	0.126	-0.126	0	0

Table 3.5: Results: Changed wages and real interest rate

Note: The values correspond to those in the initial steady state, the data, and the model with the changed parameter values respectively. The bottom row shows the absolute difference in each column between the second and third row. Wages are the region-specific wage components $w(q)$.

observed increase. The effect of combining higher wages and a lower interest rate seems to be almost additive.

To formalize the conclusions and put a number of the explanatory power of the model, it is helpful to define a statistic for the national house price index and house price dispersion. As my measure of the national house price level, I will use the population-weighted average increase in local house prices.

$$P_h = L(q^h)p_h(q^h) + L(q^l)p_h(q^l). \tag{3.20}$$

As I have data on both the price level and the population share in the two regions, it is straight forward to compare the model to the data and get a number for the explanatory power of my model. A deviation of the model’s national price index from the data can come from one of two things. Either the local prices are wrong, or the model generates a different share of the population living in the two areas. As the model generates a population distribution that deviates significantly from the data, I choose to use the empirical population shares as weights when calculating the national house price index.

To compare the house price dispersion in the model to the data, I use the same metric for price dispersion as in section 3.3; namely the

percentage difference in house prices:

$$\Delta^P \equiv \frac{p_h(q^h) - p_h(q^l)}{p_h(q^l)}. \quad (3.21)$$

In the data we see an increase in Δ^P from 0.263 to 0.926, meaning that price dispersion increased by 66.3 %-points.

Calculating these two statistics for the model, the explanatory power for both the national house price index and the inter-regional dispersion of house prices is significant. The model is able to account for 65.8% of the increase in the national house price index and 86.1% of the house price divergence.

3.6.2 The role of housing supply

To explore the role of housing supply for my results, I conduct a series of experiments where I let the housing supply elasticity $E_h(q)$ increase in the low-productive region and decrease in the high-productive region. I let this change be equally large in both regions, solve the model, and then compare prices and population across the different calibrations. To get a sense of the size of these changes, the most extreme calibration I try is letting $E(q)$ change by 1, from (1.45, 1.67) to (0.45, 2.67). The difference in elasticities in the latter calibration corresponds to the estimated difference in supply elasticity between Tampa, FL and Oklahoma City, OK in Saiz (2010), which rank as the 20th and 88th most inelastic MSAs out of the 95 metropolitan areas in his sample.

The horizontal axis in figure 3.4 indicates the calibration used for the local supply elasticities when solving for the steady state with higher wages and a lower interest rate. The left-most point is the solution for the baseline calibration. Figure 3.4a shows that when the elasticities move further apart, price dispersion falls somewhat. Since the marginal household needs to be indifferent about where

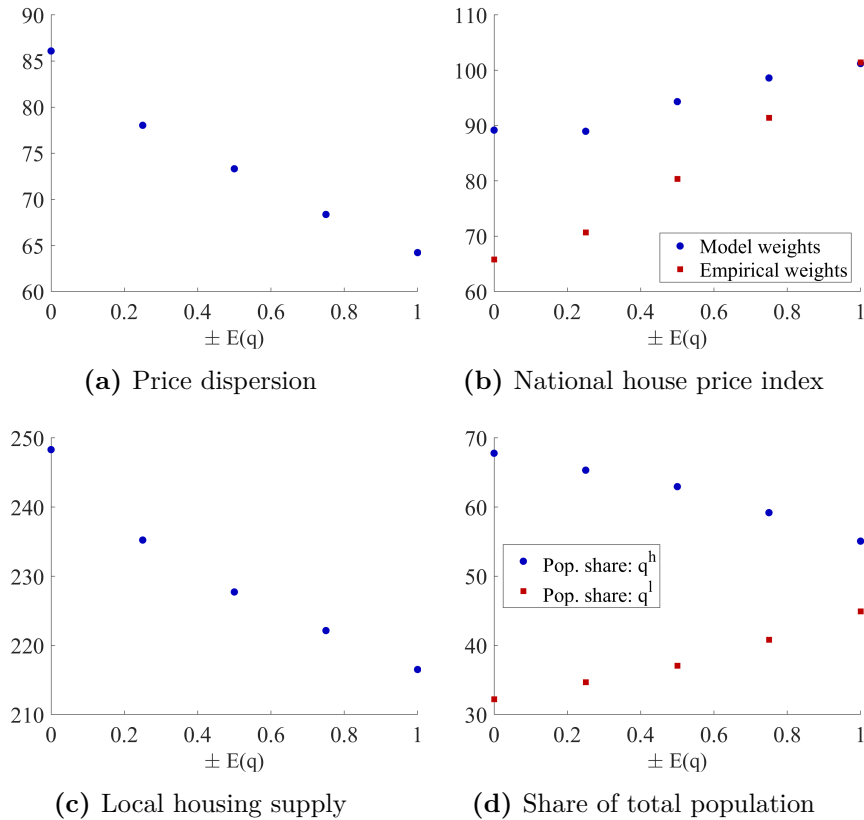


Figure 3.4: Prices and location choices for different calibrations of local housing supply elasticities

Note: Each point represents the steady state with a lower interest rate and higher wages, but for different calibrations of $E(q)$. Figures 3.4a, 3.4b, and 3.4d are in percent. The former two report the model's explanatory power, whereas the latter reports the share of households residing in each region. Figure 3.4b is calculated following equation 3.20, with the two different markers indicating whether the model generated or the empirical population shares are used to weigh the local house prices together.

to live, any change that makes one region more attractive than the other has to be offset by an endogenous change in some other region specific component. In this model, this component is the user cost of housing. The elasticity of the user cost to a change in the house price is increasing in the house price level. When houses are expensive, the land rent is high. As emphasized in section 3.3, the land rent moves 1-to-1 with the price level. This implies that when the price level is high, a fairly low price dispersion suffices to ensure that the marginal household is indifferent between the two regions.¹²

As the supply elasticities become more dispersed the total supply of housing also falls, as illustrated in figure 3.4c. When the supply of housing is lower, the national price level is higher, as figure 3.4b illustrates. This effect is quite strong. In other words, the result regarding the effect of wages and the interest rate on the national house price level is fairly sensitive to the calibration of the supply side of the housing market.¹³

Furthermore, figure 3.4 also reveals that the supply of housing has a large impact on the spatial distribution of people. As the relative price acts as a compensating differential, price dispersion is not directly related to the size of the housing stock. The differences in supply elasticity then only affects the quantity of housing and through that the amount of households living in each location. Building more houses in places such as San Francisco or Boston will not lower prices in those locations relative to the rest of the country. It will only induce more people to move there. This result is not only interesting in its own right, but also because it is a candidate for how to align the model with the data. The baseline calibration generated too much

¹²This can be seen formally in equation (3.3), where dispersion is decreasing in $p_h(q')$

¹³An inelastic housing stock is often assumed in these type of models. Sommer et al. (2013), who study house price fundamentals in a one-region economy, is an example of this.

movement, with over 67% of the population choosing to reside in the productive area. With a calibration where the supply elasticities are further apart, the model can instead generate a spatial distribution that is in line with data. Interestingly, when the elasticities are changed sufficiently much, the model matches both the spatial distribution and the national house price level almost perfectly, while still being able to explain two thirds of the price dispersion.

3.6.3 Does migration matter?

The results so far have included a large response in location choices of the households. Both increased wage dispersion and a lower interest rate encourages agents to move from the low-productivity region to the high-productivity region. To see what role location choices play in driving house prices, I again run an experiment where I change both labor productivity and the interest rate. However, this time I force the solution to be such that the location choices of all households are the same as in the initial steady state. Any change in prices is then driven purely by an intensive margin response. The results from this exercise are displayed in table 3.6.

	Prices		Pop. share		Wages	
	q^h	q^l	q^h	q^l	q^h	q^l
<i>Baseline</i>	1.000	0.792	0.515	0.485	1.000	0.893
<i>Data</i>	1.586	0.824	0.552	0.448	1.248	1.030
<i>Model</i>	1.173	0.906	0.515	0.485	1.248	1.030
<i>Difference</i>	-0.413	0.082	-0.037	0.037	0	0

Table 3.6: Results: Fixed location choices

Note: The values correspond to those in the initial steady state, the data, and the model with the changed parameter values respectively. The bottom row shows the absolute difference in each column between the second and third row. Wages are the region-specific wage components $w(q)$.

The main takeaway from this section is that the model now does

a much worse job of explaining the price divergence. Prices go up significantly in both regions, and the model now only generates around 5% of the increase in price dispersion as defined in (3.21). This is much less than the 86.1% increase generated when the model allowed for households to freely choose where to live and consume housing. In other words: the bulk of the divergence in house prices is due to the desire to migrate from cheap to expensive areas.

In terms of the national house price index, the explanatory power also falls. The model was able to explain 65.8 % of the total price increase in the model with migration. Now this number has fallen to 44.6 %. The reason for this is that by forcing households to live in the low-productive region, the average wage increase is lower and there are more people facing the relatively elastic housing supply that this region is endowed with. When house price fundamentals change and demand increases, the equilibrium is characterized by a larger response in the quantity of housing and a smaller response in the price.

Although the importance of migration is interesting in its own right, it casts doubt on the model's ability to explain the divergence of house prices. If local house prices are driven by the desire to migrate, and the migration flows are counter-factually large, how can we believe anything that the model says about house prices? One reason for this non-alignment between model and data is dynamics. It is possible that the model's steady state solution gives a good solution for where the economy is heading, but that we are still along the transition path to that point. To assess the merit of this line of reasoning, I will next solve for the transition path between the two steady states.

3.6.4 Transitional dynamics

Migration is slow, and new housing units are typically not built overnight. This makes assessing the model's explanatory power based only

on comparisons of steady states problematic. As I set out to explain a pattern in prices observed over the last two decades, accounting for transitional dynamics is crucial. One big advantage of my model is that it models households' housing demand and location choices explicitly, and does so in a life-cycle setting. This allows me to make predictions for how households' behaviour will change both in the short and the long run, in response to changes in house price fundamentals.¹⁴

To do so, I solve for the transition path between the initial steady state and the steady state where both the labor productivities and the real interest rate are changed. The experiment amounts to changing the interest rate and wages linearly over a 15 year period. The transition is characterized by perfect foresight, meaning that all agents know at the beginning of the transition path exactly how the future is going to play out with respect to prices, wages, and the interest rate.¹⁵ The results are presented in figure 3.5.

As depicted in 3.5a, the dispersion of prices adjusts very quickly. This is due to the perfect foresight. Since migration is costly, households are very forward looking in terms of their location decision. As the relative price needs to make the marginal household indifferent between the two locations, price dispersion immediately jumps up in the first period of transition, even though little changes in fundamentals have yet taken place. The remaining price divergence takes place gradually, as fundamentals gradually evolve. After 15 years, wages and the interest rate have reached their new steady state levels, and this is also when price dispersion converges.

Turning our attention to the location choices of households, the convergence is slow compared to prices. Due to transaction costs of housing and the utility cost of migration, older households are not

¹⁴The urban economics literature often exerts significant effort to capture differences between locations, but model households in a static way. For example, see recent contributions by Eeckhout et al. (2014) or Hsieh and Moretti (2019)

¹⁵More details on the transition path are provided in the appendix.

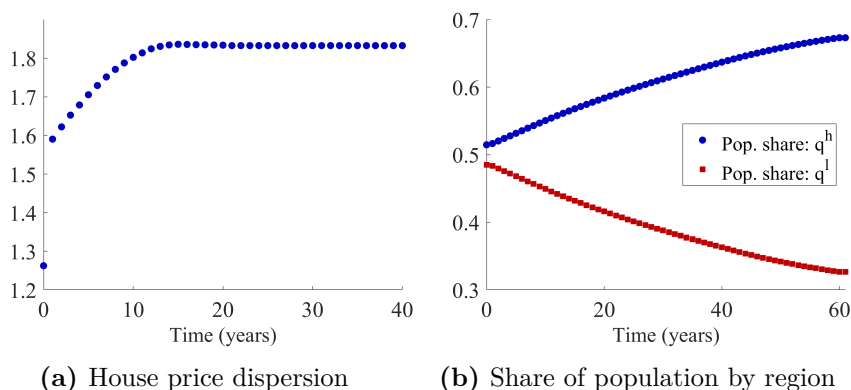


Figure 3.5: Prices and location choices over the transition path

Note: Each point represents a point in time during a perfect foresight transition from the initial steady state to a steady state with a lower interest rate and higher wages. Both the real rate and wages change permanently and unexpectedly. Figure 3.5a is defined as in equation 3.21 and indicated on the vertical axis. Figure 3.5b shows the share of the population residing in each region.

very keen on moving despite the changes in wages and the interest rate. Over time they are replaced by new households who are free to locate wherever they want, and the economy gradually converges to the new equilibrium. While the change in where people live is still large, the transitional dynamics help to explain a significant part of the misalignment between model and data that we saw earlier. After 23 years, price dispersion has reached its new high plateau, whereas only about half of the change in location choices has taken place.

It is also important to remember the perfect foresight assumption. In reality, the idea that realized changes in local wages and the secular decline in the interest rate were perfectly predicted in 1995 is not believable. If households instead learned gradually about the changes in fundamentals, prices and location choices would most likely converge even slower.¹⁶

¹⁶A way to address this problem is to solve for a transition where the economy

3.6.5 Who are the winners and losers in the housing market?

The fine structure of the household side of the model allows me not only to study aggregate patterns, but also changes at the micro level. One avenue that is possible to explore is the welfare implications of this episode. Who are the winners and losers from the changes in house price fundamentals? And how large are the welfare gains and losses?

As my measurement of welfare gains, I use the equivalent variation EV . I define this as the size to the one-time cash transfer required in the initial steady state to make the households indifferent between that initial steady state and experiencing the transition to the new steady state with higher wages and a lower interest rate.

$$V_j^{init}(m, h, x + EV, p, q) = V_{j,t}^{tr}(m, h, x, p, q) \quad (3.22)$$

Note that EV is measured in terms of units of the tradeable numeraire good. To make the numbers more tractable and comparable across households, I divide each household's equivalent variation by their annual earnings. The numbers reported below should therefore be interpreted as how many annual wages the household requires as a lump-sum transfer to be indifferent between the steady state and the transition.

Figure 3.6 shows the EV for all agents at age $j = 15$, by tenure and region of residence.¹⁷ Two facts stand out. First, the welfare gains are sizeable. Second, the gains are much larger for one specific group: homeowners in the high-productive region q^h . The reason for

is repeatedly hit by permanent shocks. Technically, this would constitute solving for a series of transition paths departing from each other, which is a very time consuming task. I leave this task for the future.

¹⁷By focusing on one particular age group, I remove the effect of income changing over the life-cycle. This makes the histogram easier to interpret. The results are qualitatively similar for other cohorts of working age.

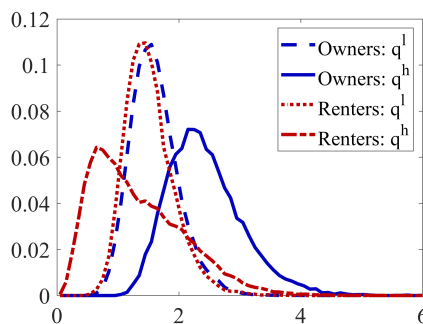


Figure 3.6: Welfare gains in the first period of transition

Note: The figure shows four overlapping histograms of the equivalent variation for households at age $j = 15$, in the first period of transition.

this pattern is fairly straight forward. At the preceding age $j = 14$, all households make decisions on region of residence, ownership, savings, and house size, under the assumption that the aggregate conditions of the economy will remain the same. When the economy enters the transition, they realize that wages will increase in the future, that they will be increasingly different across locations, and that interest rates will be lower. These facts directly lead to increased welfare, and more so for those already in the high-productive region where wages go up the most.

In addition to changed fundamentals, prices adjust to clear the housing market. In particular, the house price goes up significantly in q^h . This leads to a discrete increase in wealth among those who already own houses in this region. The effect is significant, with some homeowners realizing welfare gains equivalent to a lump-sum transfer of four years worth of wages. However, for renters in this region the sharp increase in prices is a bad thing, as it makes it more difficult to become a homeowner and leads to an increase in rents. Therefore, these households see the lowest welfare gains of all groups, despite living in the region that see wages go up the most.

3.7 Concluding remarks

The evolution of house prices in the U.S. saw a trend break in the middle of the 1990's. From approximately 1995 and onwards, house prices have gone up significantly at the national level. At the same time, prices at the local level started to diverge. Labor markets where prices were relatively high in the 90's have seen sizeable price increases, whereas relatively affordable areas have experienced more modest changes. By building, calibrating, and running policy experiments using a Rosen-Roback model with heterogeneous agents and housing markets modelled in great detail, I set out to investigate what has caused this. Why have house prices gone up at the national level? Why have they diverged at the local level? And what are the welfare consequences of this episode?

The main result of this paper is that the observed changes in labor productivity across locations and the secular decline in the real interest rate can explain most of the evolution of house prices in the U.S, both at the national and at the local level. Together, these drivers can explain around 86 % of the increase in house price dispersion between regions and 66 % of the increase in the national house price index. When explicitly accounting for dynamics by solving for the transition path, I find that prices adjust quickly due to the forward-looking behaviour of the households. This rapid change in prices leads to a significant increase in the wealth of those who already own a home located in regions where prices go up. In terms of welfare, these wealth gains are equivalent to receiving a one-time transfer equal to a couple of years worth of labor earnings.

I also show that the extensive margin is key for these results. Both the fall in the real rate and the increased dispersion of wages lead to a desire among households to move from the low-productive to the high-productive region. By allowing for households to freely choose their region of residence, this desire increases demand for housing

in the already expensive region and lowers demand in the affordable region. When I conduct an experiment where households' locations are not allowed to change, the model is only able to explain around 5 % of the increased dispersion in prices. Although allowing for migration implies a significant change in where households live in equilibrium, migration is slow and costly. This helps align the model's prediction of price divergence driven by a desire to migrate with the empirical fact that little migration has actually taken place.

I also explore the role of region-specific housing supply elasticities. Solving the model for different calibrations of housing supply elasticities, I show that there is a significant effect on the national house price level and the share of households residing in each region. However it has a relatively small effect on relative prices. This is a consequence of the role of house prices as a compensating differential. The relative house price needs to be such that it makes both regions equally attractive. How attractive it is to live in a given region is determined by wages and the interest rate, not how large the stock of housing is.

Turning attention to the policy implications of these results, I see two that are particularly interesting. First and foremost, since the evolution of house prices can be well explained by fundamentals, this paper leaves little room for the existence of a house price bubble; both at the local and at the national level. Soaring house prices in areas such as San Francisco, Boston, or New York City, should not necessarily raise concerns among policy makers or homeowners. Second, although prices are in line with fundamentals, recent history has shown that these can change fairly quickly. If interest rates go up again, not even the exceptional productivity levels and wages in the Bay Area can motivate prices at the current levels. Houses, and with that the majority of people's asset holdings, will decrease in value in these areas. Moreover, the model shows a strong link between migration flows, prices, and fundamentals. A hypothetical increase

in the real rate would not only lead to falling prices in expensive areas, but would also revert migration flows from these productive places to cities with lower wage levels. Further discussing the exact consequences of such an event is beyond the scope of this paper, but an interesting avenue to investigate further. I believe my results show evidence that rising interest rates will even out house prices across the U.S. and that a significant share of this comes from a reversal of migration flows. With the interest rate being a global price, this line of reasoning is likely to apply to other economies as well.

As with any theory-driven paper in economics, the model can never capture all aspects of an infinitely complicated reality. One important feature that has been ignored in this paper is the role of endogenous sorting and any feedback effects this might have. Diamond (2016) highlights that living among high-skilled workers is an amenity in itself, which drives up housing demand and prices. De La Roca and Puga (2017) and Keuschnigg et al. (2019) show that the wage premium of moving to high productive cities is higher for high skilled individuals, even within narrowly defined categories of worker types, which gives rise to sorting on skill. Relatedly, Glaeser (1999) discusses the role of human capital spillovers and how this can create a causal link from demographic composition to wages. All these channels are excluded from my analysis, but I do recognize them as important avenues for future research.

References

- Bell, F. C. and M. L. Miller (2005, August). Life tables for the United States Social Security Area 1900-2100. Actuarial study No. 120, Social Security Administration.
- Boar, C., D. Gorea, and V. Midrigan (2020). Liquidity constraints in the U.S. housing market. *Working Paper*.
- Carroll, C. D. and A. A. Samwick (1997). The nature of precautionary wealth. *Journal of Monetary Economics* 40(1), 41–71.
- Chambers, M., C. Garriga, and D. E. Schlagenhauf (2009). Housing policy and the progressivity of income taxation. *Journal of Monetary Economics* 56(8), 1116–1134.
- Cocco, J. F., F. J. Gomes, and P. J. Maenhout (2005). Consumption and portfolio choice over the life cycle. *Review of Financial Studies* 18(2), 491–533.
- Davis, A. M. and M. Palumbo (2008). The price of residential land in large us cities. *Journal of Urban Economics* 63(1), 352–384.
- De La Roca, J. and D. Puga (2017). Learning by working in big cities. *Review of Economic Studies* 84(1), 106–142.
- Diamond, R. (2016). The determinants and welfare implications of us workers’ diverging location choices by skill: 1980-2000. *American Economic Review* 106(3), 479–524.
- Díaz, A. and M. J. Luengo-Prado (2008). On the user cost and homeownership. *Review of Economic Dynamics* 11(3), 584–613.
- Eeckhout, J., R. Pinheiro, and K. Schmidheiny (2014). Spatial sorting. *Journal of Political Economy* 122(3), 554–620.

- Favilukis, J., S. C. Ludvigson, and S. Van Nieuwerburgh (2017). The macroeconomic effects of housing wealth, housing finance, and limited risk sharing in general equilibrium. *Journal of Political Economy* 125(1), 140–223.
- Floetotto, M., M. Kirker, and J. Stroebe (2016). Government intervention in the housing market: Who wins, who loses? *Journal of Monetary Economics* 80, 106–123.
- Garriga, C. and A. Hedlund (2018). Housing finance, boom-bust episodes, and macroeconomic fragility. *Working Paper*.
- Gervais, M. (2002). Housing taxation and capital accumulation. *Journal of Monetary Economics* 49(7), 1461–1489.
- Glaeser, E. (1999). Learning in cities. *Journal of Urban Economics* 46(2), 254–277.
- Glaeser, E. and J. Gyourko (2003). The impact of building restrictions on housing affordability. *FEB New York Economic Policy Review* 9(2), 21–39.
- Glaeser, E. and J. Gyourko (2018). The economic implications of housing supply. *Journal of Economic Perspectives* 32(1), 3–30.
- Glaeser, E., J. Gyourko, and R. Saks (2005). Why is manhattan so expensive? regulation and the rise in housing prices. *Journal of Law and Economics* 48(2), 331–369.
- Greenwald, D. (2018). The mortgage credit channel of macroeconomic transmission. *Working Paper*.
- Gruber, J. W. and R. F. Martin (2003). Precautionary savings and the wealth distribution with illiquid durables. *International Finance Discussion Papers* 773.

- Güvenen, F. (2009). An empirical investigation of labor income processes. *Review of Economic Dynamics* 12(1), 58–79.
- Gyourko, J., A. Saiz, and A. Summers (2008). A new measure of the local regulatory environment for housing markets: The wharton residential land use regulatory index. *Urban Studies* 45(3), 693–729.
- Harris, E. (2005, November). Effective marginal tax rates on labor income. A CBO paper, Congressional Budget Office.
- Hedlund, A., F. Karahan, K. Mitman, and S. Ozkan (2016). Monetary policy, heterogeneity, and the housing channel. *Working Paper*.
- Hornbeck, R. and E. Moretti (2019). Who benefits from productivity growth: Direct and indirect effects of local tfp growth on wages, rents, and inequality. *Working paper*.
- Hsieh, C.-T. and E. Moretti (2019). Housing constraints and spatial misallocation. *American Economic Journal: Macroeconomics* 11(2), 1–39.
- Kaplan, G., K. Mitman, and G. Violante (2020). The housing boom and bust: model meets evidence. *Journal of Political Economy*, Forthcoming.
- Keuschnigg, M., S. Mutgan, and P. Hedstrom (2019). Urban scaling and the regional divide. *Science Advances* 5(1).
- King, M. and D. Low (2014). Measuring the world interest rate. *NBER working papers* (19887).
- Kiyotaki, N., A. Michaelides, and K. Nikolov (2011). Winners and losers in housing markets. *Journal of Money, Credit and Banking* 43(2-3), 255–296.
- Knoll, K., M. Schularick, and T. Steger (2014). No price like home: Global house prices, 1870-2012. *Working Paper*.

- Molloy, R., C. Smith, and A. Wozniak (2011). Internal migration in the united states. *Journal of Economic Perspectives* 25(3), 173–196.
- Moretti, E. (2011). Local labor markets. *Handbook of Labor Economics* 4, 1237–1313.
- Roback, J. (1982). Wages, rent, and the quality of life. *Journal of Political Economy* 90(2), 191–229.
- Rosen, S. (1979). Wage-based indexes of urban quality of life. *Current Issues in Urban Economics*.
- Saiz, A. (2010). The geographic determinants of housing supply. *Quarterly Journal of Economics* 125(3), 1253–1296.
- Sommer, K. and P. Sullivan (2018). Implications of US tax policy for house prices, rents, and homeownership. *American Economic Review* 108(2), 241–74.
- Sommer, K., P. Sullivan, and R. Verbrugge (2013). The equilibrium effect of fundamentals on house prices and rents. *Journal of Monetary Economics* 60(7), 854–870.
- van Nieuwerburgh, S. and P.-O. Weill (2011). Why has house price dispersion gone up? *Review of Economic Studies* 77(4), 1567–1606.

3.A Calibration details

The income process

Estimation

To estimate the income process, I use data from the PSID for the years 1970 to 1992. The choice of years is partly motivated by the PSID becoming a biannual survey after 1992, and partly because 1992 is roughly the time period I think of the initial steady state as representing. I clean the data by dropping non-respondents, households who were part of the Survey of Economic Opportunities subsample, disabled, retired, students, and housewives. I also drop all households with female heads, as they make up a very small amount of the remaining observations.

I then proceed by making further restrictions to the sample, as I want to focus on earnings of those who have a strong attachment to the labor force. Following the steps of Guvenen (2009), I only keep households where the head has annual work hours between 520 (10 hours per week) and 5110 (14 hours per day), the head is between 20 and 64 years old, the head appears in at least 15 of the survey years, and the average hourly earnings is between \$2 and \$400 in 1993 dollars where I use data series CES0500000030 in the Current Employment Statistics provided by the Bureau of Labor Statistics to back out the bounds for earlier years.

With this data I can then run my estimation procedures. I start by regressing annual earnings on age dummies for all ages, a dummy for marital status, and the number of family members. I control for household fixed effects and then extract the predicted values. For smoothing purposes I fit a third order polynomial to this series and use this as my estimate for the life-cycle component g_j .

Next, I estimate the shock variances σ_η and σ_v . This follows the strategy in Carroll and Samwick (1997). First, define the logarithm of

earnings less the household- and age-fixed components

$$\log(\hat{w}_{ij}) = \log(w_{ij}) - \omega_i - g_j - \log(w(q)) = \eta_{ij} + v_{ij}.$$

Next, define the d -period difference in $\log(\hat{w}_{ij})$ for a household i as

$$\begin{aligned} r_{id} &= \log(\hat{w}_{i,j+d}) - \log(\hat{w}_{ij}) \\ &= \eta_{i,j+1} + \eta_{i,j+2} + \dots + \eta_{i,j+d} + v_{i,j+d} - v_{i,j} \\ &\quad + \log(w(q_{i,j+d})) - \log(w(q_{i,j})). \end{aligned}$$

As I do not observe region in the data, I assume that the difference between the last two terms is zero. Using the fact that both the transitory and the permanent shocks are i.i.d., the variance of r_{id} can be written as

$$\text{Var}(r_{ij}) = d\sigma_{\eta}^2 + 2\sigma_v^w.$$

It is straight forward to estimate the two parameters by OLS.

Last, I need an estimate for the variance of household fixed effects σ_{ω} . I simply calibrate this to ensure that the variance in earnings across households in the initial period of my model corresponds to the variance in the data at age 23. As I know all other variance terms, this means ω_i will pick up the residual variance not accounted for by the other components.

Variable definitions

Age of head is constructed by taking the age when the household head is first observed and adding the number of years between the first and current observation. This ensures that there are no two-year jumps or unchanged ages between survey years. Variable name in 1992: V20651 *Family composition* is the number of members less the number of adults. This is constructed using data on the family size

and subtracting the number of adults. Variable names in 1992: V20398 and V20397. *Household earnings* w_{ij} is the sum of labor income for both the head and the wife, deflated by CPI. Variable names in 1992: V21484 and V20436. *CPI* is taken for the Bureau of Labor Statistics. I use the historical CPI for all urban consumers, U.S. city average of all items.

Wages and prices

To calibrate the location specific component of income $w(q)$, I use data from the U.S. census in 1990. I start by dropping observations that are likely to lack a strong attachment to the labor force. This means dropping women, people outside the age range 23-61, agents who work less than 30 hours in a typical week, people who work less than 40 weeks per year, and have earnings below 7 dollars per hour. I also drop those who lack data on any of these characteristics, and those who do not reside in any MSA.

Next, I use the data to calculate the average hourly earnings per region. When calculating the averages, I use the weights provided in the dataset. To find the region specific earnings components in the new steady state, I follow the exact same procedure using the 2018 American Community Survey instead.

House prices are calculated by combining data from the 2005 wave of the ACS with the Freddie Mac House Price Index. For each MSA, I use the ACS to find the median house price. As the ACS presents the median value separately for households with and without mortgages, I use the weighted average of these two medians as an estimate of the overall price level in the MSA. As weights I use the number of observations in each of these two categories. Normalizing the FMHPI to one in 2005, I can then trace out the regional median house price over time by multiplying the median price in 2005 with the FMHPI in each MSA at each point in time. Last, I deflate this using the

non-housing part of the consumer price index for the U.S. provided by the BLS.

3.B Equilibrium definitions

Households are heterogeneous with respect to age $j \in \mathcal{J} \equiv \{1, 2, \dots, J\}$, location $q \in \mathcal{Q} \equiv \{1, 2\}$, permanent earnings $p \in \mathcal{P} \equiv \mathbb{R}_{++}$, mortgage $m \in \mathcal{M} \equiv \mathbb{R}_+$, owner-occupied housing $h \in \mathcal{H} \equiv \{0, \underline{h}, \dots, \bar{h} = \bar{s}\}$, and cash-on-hand $x \in \mathcal{X} \equiv \mathbb{R}_{++}$. Let $\mathcal{Z} \equiv \mathcal{Q} \times \mathcal{P} \times \mathcal{M} \times \mathcal{H} \times \mathcal{X}$ be the non-deterministic state space with $\mathbf{z} \equiv (q, p, m, h, x)$ 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 $P(\mathcal{H})$ and $P(\mathcal{Q})$ the power sets of \mathcal{H} and \mathcal{Q} , and define $\mathcal{B}(\mathcal{Z}) \equiv \mathbf{P}(\mathcal{Q}) \times \mathbf{B}(\mathbb{R}_{++}) \times \mathbf{B}(\mathbb{R}_+) \times P(\mathcal{H}) \times \mathbf{B}(\mathbb{R}_{++})$. Further, let \mathbb{M} be the set of all finite measures over the measurable space $(\mathcal{Z}, \mathcal{B}(\mathcal{Z}))$. Then $\Phi_j(Z) \in \mathbb{M}$ is a probability measure defined on subsets $Z \in \mathcal{B}(\mathcal{Z})$ 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 , and the share of households residing in each region at age $j = 1$ by $\tilde{L}(q)$.

Definition 1. An initial stationary recursive competitive equilibrium is a collection of value functions $V_j(\mathbf{z})$ with associated policy functions $\{c_j(\mathbf{z}), s_j(\mathbf{z}), h'_j(\mathbf{z}), m'_j(\mathbf{z}), b'_j(\mathbf{z}), q'_j(\mathbf{z})\}$ for all j ; prices $(p_r(q), w(q))$ and housing supply parameter $\Upsilon(q)$ for all q ; an initial allocation of labor $\tilde{L}(q)$ in each region q at $j = 1$; a set of amenity values $\psi(q)$ for each location q ; and a distribution of agents' states Φ_j for all j such that:

1. Given prices $(p_r(q), w(q))$, $V_j(\mathbf{z})$ solves the Bellman equation with the corresponding set of policy functions $\{c_j(\mathbf{z}), s_j(\mathbf{z}), h'_j(\mathbf{z}), m'_j(\mathbf{z}), b'_j(\mathbf{z}), q'_j(\mathbf{z})\}$ for all j .
2. The rental price per unit of housing service $p_r(q)$ is given by equation (3.14) for all q .

3. The region-specific wage component $w(q)$ is given by equation (3.15) for all q .
4. The amenity values $\psi(q)$ ensure the allocation $\tilde{L}(q)$ of workers in the initial period $j = 1$ is consistent with optimality

$$\mathbb{E}\{V_1(q)\} = \mathbb{E}\{V_1(q')\} \forall (q, q') \in \mathcal{Q} \times \mathcal{Q}$$

5. Given $\tilde{L}(q)$, the total number of households in each region q is consistent with the data
6. The housing supply parameter $\Upsilon(q)$ ensures that the quantity of the total housing stock is given by total demand for housing services for all q

$$\Upsilon_h p_h(q)^{E_h(q)} = \sum_{\mathcal{J}} \Pi_j \int_{\mathcal{Z}} s_j(\mathbf{z}) d\Phi_j(\mathcal{Z}).$$

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

$$\Phi_{j+1}(\mathcal{Z}) = \int_{\mathcal{Z}} Q_j(\mathbf{z}, \mathcal{Z}) d\Phi_j(\mathcal{Z}),$$

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

Definition 2. A new stationary recursive competitive equilibrium is a collection of value functions $V_j(\mathbf{z})$ with associated policy functions $\{c_j(\mathbf{z}), s_j(\mathbf{z}), h'_j(\mathbf{z}), m'_j(\mathbf{z}), b'_j(\mathbf{z}), q'_j(\mathbf{z})\}$ for all j ; prices $(p_h(q), p_r(q), w(q))$ for all q ; an allocation for labor $\tilde{L}(q)$ in each region q at age $j = 1$; and a distribution of agents' states Φ_j for all j such that:

1. Given prices $(p_h(q), p_r(q), w(q))$, $V_j(\mathbf{z})$ solves the Bellman equation with the corresponding set of policy functions $\{c_j(\mathbf{z}), s_j(\mathbf{z}), h'_j(\mathbf{z}), m'_j(\mathbf{z}), b'_j(\mathbf{z}), q'_j(\mathbf{z})\}$ for all j .
2. Given $p_h(q)$, the rental price per unit of housing service $p_r(q)$ is given by equation (3.14) for all q .
3. The region-specific wage component $w(q)$ is given by equation (3.15) for all q .
4. Given prices $(p_h(q), p_r(q), w(q))$, the allocation $\tilde{L}(q)$ of workers in the initial period $j = 1$ is consistent with optimality

$$\mathbb{E}\{V_1(q)\} = \mathbb{E}\{V_1(q')\} \quad \forall (q, q') \in \mathcal{Q} \times \mathcal{Q}$$

5. Given prices and initial location choices, the quantity of the total housing stock is given by equation (3.16) and housing markets clear in each region q

$$\Upsilon_h p_h(q)^{E_h(q)} = \sum_{\mathcal{J}} \Pi_j \int_{\mathcal{Z}} s_j(\mathbf{z}) d\Phi_j(Z).$$

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

$$\Phi_{j+1}(\mathcal{Z}) = \int_{\mathcal{Z}} Q_j(\mathbf{z}, \mathcal{Z}) d\Phi_j(Z),$$

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

Definition 3. Let $\Phi_{tr,jt}(Z_t) \in \mathbb{M}$ be a probability measure defined on subsets $Z_t \in \mathcal{B}(\mathcal{Z})$ that describes the distribution of individual states across agents with age $j \in \mathcal{J}$ at time period t .

Then, given a sequence of interest rates $\{r_t\}_{t=1}^{t=\infty}$, a sequence of housing supply parameters $\{\Upsilon_{h,t}(q)\}_{t=1}^{t=\infty}$, and productivity parameters $\{Z_t(q)\}_{t=1}^{t=\infty}$, a transitional recursive competitive equilibrium is a sequence of value functions $\{V_{jt}(\mathbf{z})\}_{t=1}^{t=\infty}$ with associated policy functions $\{c_{jt}(\mathbf{z}), s_{jt}(\mathbf{z}), h'_{jt}(\mathbf{z}), m'_{jt}(\mathbf{z}), b'_{jt}(\mathbf{z}), q'_{jt}(\mathbf{z})\}_{t=1}^{t=\infty}$ for all j ; a sequence of prices $\{(p_{h,t}(q), p_{r,t}(q), w_t(q))\}_{t=1}^{t=\infty}$; a sequence of initial location choices of households at age $j = 1$ $\{\tilde{L}(q)\}_{t=1}^{t=\infty}$; and a distribution of agents' states $\{\Phi_{tr,jt}\}_{t=1}^{t=\infty}$ for all j such that:

1. Given prices $\{(p_{h,t}(q), p_{r,t}(q), w_t(q))\}_{t=1}^{t=\infty}$ and parameters $\{(r_t, Z_t(q))\}_{t=1}^{t=\infty}$, $V_{jt}(\mathbf{z})$ solves the Bellman equation with the corresponding set of policy functions $\{c_{jt}(\mathbf{z}), s_{jt}(\mathbf{z}), h'_{jt}(\mathbf{z}), m'_{jt}(\mathbf{z}), b'_{jt}(\mathbf{z}), q'_{jt}(\mathbf{z})\}$ for all j and t .
2. Given $\{p_h(q)\}_{t=1}^{t=\infty}$, the rental price per unit of housing service $\{p_r(q)\}_{t=1}^{t=\infty}$ is given by equation (3.14) for all q .
3. Given $\{Z_t(q)\}_{t=1}^{t=\infty}$, the region-specific wage component $\{w_t(q)\}_{t=1}^{t=\infty}$ is given by equation (3.15) for all q .
4. Given prices $\{(p_h(q), p_r(q), w_t(q))\}_{t=1}^{t=\infty}$, the allocation $\{\tilde{L}(q)\}_{t=1}^{t=\infty}$ of workers in the initial period $j = 1$ is consistent with optimality

$$\mathbb{E}\{V_{1t}(q)\} = \mathbb{E}\{V_{1t}(q')\} \quad \forall (q, q') \in \mathcal{Q} \times \mathcal{Q} \text{ for all } t$$

5. Given prices $\{(p_{h,t}(q), p_{r,t}(q), w_t(q))\}_{t=1}^{t=\infty}$ and the sequence $\{\Upsilon_{h,t}(q)\}_{t=1}^{t=\infty}$, the quantity of the total housing stock is given by equation (3.16) and housing markets clear in each region q

$$\Upsilon_{h,t} p_{h,t}(q)^{E_h(q)} = \sum_{\mathcal{J}} \Pi_j \int_Z s_{jt}(\mathbf{z}) d\Phi_{tr,jt}(Z) \quad \forall t.$$

6. The distribution of states $\Phi_{tr,jt}$ is given by the following law of

motion for all $j < J$

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

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

3.C Solution algorithm

The number of grid points used for loan-to-value N_{LTV} , housing N_H , cash-on-hand N_X , permanent earnings N_P , and bond-to-earnings N_B are 21, 10, 50, 9, and 25 respectively. A more detailed account of the solution method, such as the discretization of the state space, is outlined in chapter 1 of this thesis. Below, I list the algorithm for solving the model using this solution method.

3.C.1 Initial steady state

To solve for the initial steady state equilibrium, I proceed in the following steps:

1. Guess a set of amenity parameters $\{\psi(q^h), \psi(q^l)\}$ where $\psi(q^l) = 0$
2. Set prices $p_h(q), w(q)$ according to the calibration
3. Solve for rents $p_r(q)$ using (3.14)
4. Solve the household problem, and obtain the value and policy functions
5. Guess the share of workers that reside in each location q in the initial period $\tilde{L}(q)$, and let the initial location be random conditional on these shares.

6. Simulate forward and back out the resulting share of households in each region $L(q)$
7. Compare the populations shares $L(q)$ to the calibration, and update the guess of $\tilde{L}(q)$ until $L(q)$ corresponds to the calibration
8. Back out the expected value functions in each location q at age $j = 1$, and use the difference to update the guess of amenities $\psi(q)$
9. Iterate on $\psi(q)$ until the indifference condition $\mathbb{E}\{V_1(q^h)\} = \mathbb{E}\{V_1(q^l)\}$ holds

3.C.2 New steady state

In the new steady state, a subset of parameters are changed and prices are allowed to change endogenously to ensure market clearing. I proceed in the following steps

1. Guess prices $p_h(q)$ in each region
2. Back out wages $w(q)$ using (3.15)
3. Solve for rents $p_r(q)$ using (3.14)
4. Solve the household problem, and obtain the value and policy functions
5. Guess the share of workers that reside in each location q in the initial period $\tilde{L}(q)$, and let the initial location be random conditional on these shares.
6. Simulate forward and back out the resulting share of households in each region $L(q)$
7. Calculate the excess demand for housing in each region.

8. Use the resulting difference in excess demand between the two regions to update the share of workers starting in each region $\tilde{L}(q)$. Repeat steps 5-7 until the excess demand for housing is the same in both regions.
9. Calculate the difference in expected value of living in each region $\hat{V} = \mathbb{E}\{V_1(q^h)\} - \mathbb{E}\{V_1(q^l)\}$. Use this to update the guess of $p_h(q^h)$, while keeping $p_h(q^l)$ fixed. Repeat steps 3-9 until $\hat{V} = 0$.
10. Use the resulting difference between housing demand and supply to update the price $p_h(q^l)$.

The procedure is repeated until the housing markets clear and all newborns are indifferent between the locations. Note that in principle it is possible that step 8 fails, that is, the excess demand cannot be equalized in both regions even when all agents of age $j = 1$ locate in the region with the lowest excess demand for housing. However, this turns out not to be a problem for any reasonable initial guess of prices.

3.C.3 Transition

Given a sequence of housing supply parameters $\{\Upsilon_{h,t}(q)\}_{t=1}^{t=\infty}$, solving the transition would follow the same procedure as the solution for the new steady state, with the difference that guesses are made over the entire sequences of prices $\{p_h(q^l), p_h(q^h)\}_{t=1}^{\infty}$ and location choices of newborns $\{\tilde{L}(q)\}_{t=1}^{\infty}$. However, the model does not provide any structure for the dynamics of housing supply, only for the steady state levels. Therefore, the path $\{\Upsilon_{h,t}(q)\}_{t=1}^{t=\infty}$ has to be assumed rather than derived, implying that the exact transition paths of prices and location choices will be heavily influenced by the assumption made.

In an earlier version of the paper, I made an assumption of the supply of housing evolving linearly over a certain number of years, and solved for the transition path of prices and location choices conditional

on this. Here, I instead assume a path for the house price $\{p_h(q^l)\}_{t=1}^\infty$ and location choices of households at the initial age $\{\tilde{L}(q)\}_{t=1}^\infty$, and back out the path of housing supply that would ensure that housing markets clear. The motivation for this is twofold. First, since the path of housing supply is assumed rather than derived, there is no reason why one way would be more “correct” than the other. Second, by making assumptions on one of the prices and initial location choices, the solution algorithm is much faster, something that is of essence in an already computationally heavy model. The solution algorithm only requires you to iterate on one of the prices $p_h(q^h)$ rather than both of them.

To solve for the transition path, I assume that the transition takes $T = 65$ periods and that $p_h(q^l)$ and \tilde{L} reach their new steady state level already in $t = 1$ and stays constant throughout the transition. The solution algorithm is then as follows

1. Guess a sequence of prices $\{p_h(q^h)\}_{t=1}^T$
2. Back out wages $\{w(q)\}_{t=1}^T$ using (3.15)
3. Solve for rents $\{p_r(q)\}_{t=1}^T$ using (3.14)
4. Solve the household problem, and obtain the value and policy functions
5. Simulate forward and back out the resulting share of labor in each region $L(q)$
6. Calculate the demand for housing in each region.
7. Calculate the difference in expected value of living in each region $\{\hat{V}_t\}_{t=1}^T = \mathbb{E}\{V_{1,t}(q^h)\}_{t=1}^T - \mathbb{E}\{V_{1,t}(q^l)\}_{t=1}^T$. Use this to update the guess of $p_h(q^h)$. Repeat all steps until $\hat{V}_t = 0 \forall t$.

The resulting path of housing demand, and consequently supply, is illustrated in figure 3.7. It evolves fairly linearly over a 60 year period.

If I had assumed the specific paths of $\{\Upsilon_{h,t}(q)\}_{t=1}^T$ that correspond to the vectors of housing demand illustrated in this figure, and instead iterated on prices and locations choices for newborns, it would have given me the same solution.

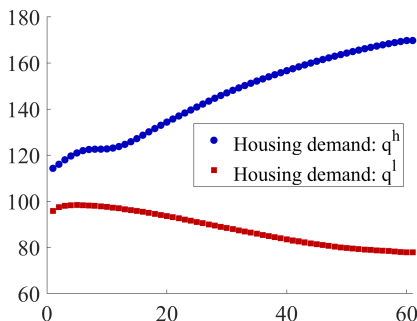


Figure 3.7: Housing demand and supply over the transition

Note: The figure shows the path of housing demand and supply in each region for all time points along the transition path.

3.D House characteristics across locations

A key assumption of the model is that one unit of housing is comparable across locations. It yields the same amount of utility, and has the same maintenance cost, no matter where the house is located. When I calibrated the initial house prices, I used data on the median house value in each MSA. This means that if houses are systematically different in their characteristics between my two groups of MSAs, then it might be that I use prices for two very different sets of houses to calibrate the price differences in my model.

To test this, I conduct a simple exercise using data from the 1997 wave of the American Housing Survey. For each MSA in the data, I run a regression on hedonics. The hedonics I include are the age of the structure, the number of rooms, the size of the house, the size

of the lot, and a quadratic term for all the hedonics except for age. For each MSA I then predict the value of the typical American house, defined as a house that has the median values of all these hedonics. Once I do that, I can repeat the calibration exercise but using these quality-adjusted prices rather than the observed median prices. The idea is that any systematic differences in house prices between the regions driven by differences in the characteristics of the local housing stock should be controlled for. With $p_h(q^h)$ normalized to 1, this exercise yields $p_h(q^l) = 0.7918$ instead of 0.7915. This suggests that the two regions in my model do not differ systematically in terms of the characteristics of the housing stock.

Sammanfattning

Denna avhandling består av tre kapitel, som alla behandlar frågor relaterade till bostads- och bolånemarknaden. Metodologiskt delar de flera egenskaper, inte minst genom att de alla använder sig av modeller med heterogena hushåll för att besvara sina respektive forskningsfrågor. Kapitlen är ordnade i kronologisk ordning, så att det först skriva kapitlet utgör kapitel 1.

I kapitel 1, Kostsamma reformer av dåliga subventioner — fallet med ränteavdraget (Costly reversals of bad policies: the case of the mortgage interest deduction), samförfattat med Karin Kinnerud och Kasper Kragh-Sørensen, studerar vi hur hushåll i USA påverkas om man tar bort ränteavdraget för bostadslån samt huruvida detta är en god idé.

Ränteavdraget är en skattesubvention som har fått en hel del uppmärksamhet i de politiska diskussionerna runt om i världen, inte minst i USA. Subventionen gör det möjligt för husägare att dra av räntebetalningar på bostadslån från sina skattepliktiga inkomster. Då avdragsrätten kan minska husägarnas skatter, minskar det i praktiken kostnaden för bolån och därmed kostnaden för att äga en bostad. Således 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 kritiserar 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 alls.

För att skapa en bättre förståelse för vem som skulle dra nytta av och vem som skulle förlora på att avskaffa ränteavdraget så 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 bostadslån. Våra resultat visar att en stor majoritet av hushållen skulle föredra ett samhälle utan ränteavdrag. I ett samhälle utan skattesubventionen efterfrågar hushåll med hög inkomst mindre egenägda bostäder. Detta fall i efterfrågan på bostäder leder till lägre priser för både ägda och hyrda bostäder, vilket är speciellt gynnsamt för hushåll med låga inkomster. Vidare, när staten inte längre subventionerar räntebetalningar på bostadslån så finns det utrymme för att sänka andra skatter. Medan enbart vissa hushåll drar nytta av ränteavdraget så gynnas alla hushåll av en lägre inkomstskatt.

Givet de stora välfärdsvinsterna av att ta bort bolånesubventionen 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 de hushåll

som hyr sitt boende upplever överstiger inte de negativa effekterna för husägarna. Vi visar också att dessa resultat även håller om avskaffandet av ränteavdraget sker gradvis eller om det tillkännages i förväg. Våra resultat pekar på att ännu färre hushåll är positiva till ett avskaffande under dessa alternativa implementeringssätt. Trots att ett mer gradvist borttagande av ränteavdraget 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, Utlåningsregler för bolån: implikationer för konsumtionsdynamik (Mortgage lending standards: implications for consumption dynamics), även detta samförfattat med Karin Kinnerud och Kasper Kragh-Sørensen, studerar vi huruvida striktare regler för bolån kan minska fallet i konsumtion under ekonomiska nedgångar. Mer specifikt studerar vi i vilken utsträckning bolåneregler påverkar i vilken omfattning hushåll ändrar sin konsumtion, när de upplever ett tillfälligt fall i värdet på sina tillgångar.

Myndigheter i många länder har infört striktare krav för bostadslån under senare år. Denna utveckling är delvis motiverad av erfarenheterna från den stora recession som följde i finanskrisens kölvatten, där områden med en större ökning av bostadslån innan krisen upplevde en kraftigare minskning av konsumtion när krisen väl 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 för hushållen att undvika en tillfällig konsumtionsminskning är just genom att öka sin skuldsättning. Genom att då begränsa möjligheterna att låna så 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 detta kapitel använder vi en modell för att utföra experiment där kontantinsatskravet och skuldkvotskravet stramas åt. Kontantinsatskravet specificerar det hur stor andel av bostadens värde som måste finansieras med eget kapital. Skuldkvotskravet begränsar storleken på bolånet i förhållande till inkomsten, genom att sätta ett tak på hur stor andel av den årliga inkomsten som får läggas på bostadsrelaterade kostnader. I våra experiment studerar vi först en permanent ändring av kontantinsatskravet från 10% till 30% och en ändring av skuldkvotskravet från 28% till 18%. Vi utforskar sedan en temporär implementering av de striktare kraven, där lånereglerna är striktare 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 andra sätt. Färre hushåll äger sin bostad, de har lägre skuldsättning och sparar i genomsnitt aningen mer. Resultatet att konsumtionsdynamiken förblir oförändrad kommer ifrån 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 utlåningsregler 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 värdet på sina tillgångar. Det är emellertid enbart under väldigt specifika omständigheter som temporärt striktare bolånekrav leder till att hushållen i genomsnitt upplever välfärdsvinster. För det första måste den ekonomiska nedgången vara stor. För det andra

behöver beslutsfattarna ha en informationsfördel, i den mening att de kan förutse nedgången, medan hushållen inte kan göra det.

I kapitel 3, Den stora husprisdivergensen — en kvantitativ undersökning av husprismetabolism (The great house price divergence: a quantitative investigation of house price fundamentals) studerar jag prisutvecklingen för bostäder i USA under de senaste 25 åren.

Det är väl känt att bostadspriserna i USA, liksom de flesta utvecklade länder, har ökat under denna tidsperiod. Tidsperioden från ungefär 1995 och framåt sticker ut som den era med den snabbaste prisökningen i modern tid. Vad som är mindre känt är att denna pristrend ser mycket olika ut mellan olika regioner. Genom att jämföra prisutvecklingen mellan amerikanska städer så finner jag något som jag kallar "husprisdivergens". Städer som var relativt billiga på 90-talet har oftast sett en mycket blygsam prisförändring, medan städer som var relativt dyra för 25 år sedan ofta fått uppleva en extremt kraftig prisuppgång. Målet med denna uppsats är att förklara dessa två trender. Varför har bostadspriserna ökat på nationell nivå? Och varför är denna nationella trend driven av platser som var relativt dyra till att börja med?

För att besvara dessa frågor så specificerar jag en modell, och använder denna för att kvantifiera vilken roll löner, realräntan och bostadsutbudselasticiteten spelar för husprisutvecklingen mellan 1995 och 2018. Förutom att stor vikt läggs på att modellen skall avbilda bostadsmarknaden väl så innefattar den även två regioner, och tillåter hushållen att flytta mellan dessa regioner enligt behag. Denna del av modellen är av yttersta vikt för att förstå prisdivergensen. Eftersom hushållen väljer att bo i den region de föredrar så måste den inter-regionala prisskillnaden vara sådan att något hushåll är indifferent mellan de båda regionerna.

Kapitlets huvudresultat är att både löner och realräntan är viktiga när det gäller att förklara bostadsprisutvecklingen. Tillsammans kan dessa två faktorer förklara ca. 86% av husprisdivergensen och 66% av

ökningen i den nationella prisnivån. Jag drar således slutsatsen att den dramatiska utveckling som vi har sett på bostadsmarknaden under de senaste 25 åren är relativt väl förklarad av husprisfundamenta.

Ett annat resultat är att husprisdivergensen är främst ett resultat av hushållens vilja att flytta. Om hushållen inte tillåts att flytta så följer det inte längre att relativpriset mellan de båda regionerna måste säkerställa att marginalhushållet är indifferent mellan de båda regionerna. Istället bestäms efterfrågan, och således bostadspriset, inom varje region enbart av efterfrågan på bostäder hos de som redan bor i regionen sedan tidigare. När jag tar bort migrationsvalet i modellen och återupprepar de tidigare experimenten så genererar modellen knappt någon husprisdivergens. Jag drar således slutsatsen är den ojämna löneutvecklingen mellan regionerna samt det globala fallet i realräntan främst leder till en vilja hos hushållen att flytta mellan regionerna. Och det är främst via denna migrationskanal som husprisfundamenta leder till att bostadsprisutvecklingen har varit så olika mellan olika regioner.

IIES monograph series

1. Michaely, Michael, *The Theory of Commercial Policy: Trade and Protection*, 1973
2. Söderström, Hans Tson, *Studies in the Microdynamics of Production and Productivity Change*, 1974
3. Hamilton, Carl B., *Project Analysis in the Rural Sector with Special Reference to the Evaluation of Labour Cost*, 1974
4. Nyberg, Lars and Staffan Viotti, *A Control Systems Approach to Macroeconomic Theory and Policy in the Open Economy*, 1975
5. Myhrman, Johan, *Monetary Policy in Open Economies*, 1975
6. Krauss, Melvyn, *International Trade and Economic Welfare*, 1975
7. Wihlborg, Clas, *Capital Market Integration and Monetary Policy under Different Exchange Rate Regimes*, 1976
8. Svensson, Lars E.O., *On Competitive Markets and Intertemporal Resources Allocation*, 1976
9. Yeats, Alexander J., *Trade Barriers Facing Developing Countries*, 1978
10. Calmfors, Lars, *Prices, Wages and Employment in the Open Economy*, 1978
11. Kornai, János, *Economics of Shortage, Vols I and II*, 1979
12. Flam, Harry, *Growth, Allocation and Trade in Sweden. An Empirical Application of the Heckscher-Ohlin Theory*, 1981
13. Persson, Torsten, *Studies of Alternative Exchange Rate Systems*.

- An Intertemporal General Equilibrium Approach*, 1982
14. Erzan, Refik, *Turkey's Comparative Advantage, Production and Trade Patterns in Manufactures. An Application of the Factor Proportions Hypothesis with Some Qualifications*, 1983
 15. Horn af Rantzien, Henrik, *Imperfect Competition in Models of Wage Formation and International Trade*, 1983
 16. Nandakumar, Parameswar, *Macroeconomic Effects of Supply Side Policies and Disturbances in Open Economies*, 1985
 17. Sellin, Peter, *Asset Pricing and Portfolio Choice with International Investment Barriers*, 1990
 18. Werner, Ingrid, *International Capital Markets: Controls, Taxes and Resources Allocation*, 1990
 19. Svedberg, Peter, *Poverty and Undernutrition in Sub-Saharan Africa: Theory, Evidence, Policy*, 1991
 20. Nordström, Håkan, *Studies in Trade Policy and Economic Growth*, 1992
 21. Hassler, John, Petter Lundvik, Torsten Persson, and Paul Söderlind, *The Swedish Business Cycle: Stylized facts over 130 years*, 1992
 22. Lundvik, Petter, *Business Cycles and Growth*, 1992
 23. Söderlind, Paul, *Essays in Exchange Rates, Business Cycles and Growth*, 1993
 24. Hassler, John A.A., *Effects of Variations in Risk on Demand and Measures of Business Cycle Comovements*, 1994
 25. Daltung, Sonja, *Risk, Efficiency, and Regulation of Banks*, 1994
 26. Lindberg, Hans, *Exchange Rates: Target Zones, Interventions and Regime Collapses*, 1994
 27. Stennek, Johan, *Essays on Information-Processing and Competition*, 1994
 28. Jonsson, Gunnar, *Institutions and Incentives in Monetary and Fiscal Policy*, 1995
 29. Dahlquist, Magnus, *Essays on the Term Structure of Interest*

Rates and Monetary Policy, 1995

30. Svensson, Jakob, *Political Economy and Macroeconomics: On Foreign Aid and Development*, 1996
31. Blix, Mårten, *Rational Expectations and Regime Shifts in Macroeconometrics*, 1997
32. Lagerlöf, Nils-Petter, *Intergenerational Transfers and Altruism*, 1997
33. Klein, Paul, *Papers on the Macroeconomics of Fiscal Policy*, 1997
34. Jonsson, Magnus, *Studies in Business Cycles*, 1997
35. Persson, Lars, *Asset Ownership in Imperfectly Competitive Markets*, 1998
36. Persson, Joakim, *Essays on Economic Growth*, 1998
37. Domeij, David, *Essays on Optimal Taxation and Indeterminacy*, 1998
38. Flodén, Martin, *Essays on Dynamic Macroeconomics*, 1999
39. Tangerås, Thomas, *Essays in Economics and Politics: Regulation, Elections and International Conflict*, 2000
40. Lidbom, Per Pettersson, *Elections, Party Politics and Economic Policy*, 2000
41. Vestin, David, *Essays on Monetary Policy*, 2001
42. Olofsgård, Anders, *Essays on Interregional and International Political Economics*, 2001
43. Johansson, Åsa, *Essays on Macroeconomic Fluctuations and Nominal Wage Rigidity*, 2002
44. Groth, Charlotta, *Topics on Monetary Policy*, 2002
45. Gancia, Gino A., *Essays on Growth, Trade and Inequality*, 2003
46. Harstad, Bård, *Organizing Cooperation: Bargaining, Voting and Control*, 2003
47. Kohlscheen, Emanuel, *Essays on Debts and Constitutions*, 2004
48. Olovsson, Conny, *Essays on Dynamic Macroeconomics*, 2004
49. Stavlöt, Ulrika, *Essays on Culture and Trade*, 2005

50. Herzing, Mathias, *Essays on Uncertainty and Escape in Trade Agreements*, 2005
51. Bonfiglioli, Alessandra, *Essays on Financial Markets and Macroeconomics*, 2005
52. Pienaar, Natalie, *Economic Applications of Product Quality Regulation in WTO Trade Agreements*, 2005
53. Song, Zheng, *Essays on Dynamic Political Economy*, 2005
54. Eissensee, Thomas, *Essays on Public Finance: Retirement Behavior and Disaster Relief*, 2005
55. Favara, Giovanni, *Credit and Finance in the Macroeconomy*, 2006
56. Björkman, Martina, *Essays on Empirical Development Economics: Education, Health and Gender*, 2006
57. Larsson, Anna, *Real Effects of Monetary Regimes*, 2007
58. Prado, Jr., Jose Mauricio, *Essays on Public Macroeconomic Policy*, 2007
59. Tonin, Mirco, *Essays on Labor Market Structures and Policies*, 2007
60. Queijo von Heideken, Virginia, *Essays on Monetary Policy and Asset Markets*, 2007
61. Finocchiaro, Daria, *Essays on Macroeconomics*, 2007
62. Waisman, Gisela, *Essays on Discrimination and Corruption*, 2008
63. Holte, Martin Bech, *Essays on Incentives and Leadership*, 2008
64. Damsgaard, Erika Färnstrand, *Essays on Technological Choice and Spillovers*, 2008
65. Fredriksson, Anders, *Bureaucracy, Informality and Taxation: Essays in Development Economics and Public Finance*, 2009
66. Folke, Olle, *Parties, Power and Patronage*, 2010
67. Drott, David Yanagizawa, *Information, Markets and Conflict*, 2010
68. Meyersson, Erik, *Religion, Politics, and Development*, 2010

69. Klingelhofer, Jan, *Models of Electoral Competition*, 2010
70. Perrotta, Maria Carmela, *Aid, Education and Development*, 2010
71. Caldara, Dario, *Essays on Empirical Macroeconomics*, 2011
72. Mueller, Andreas, *Business Cycles, Unemployment and Job Search*, 2011
73. von Below, David, *Essays in Climate and Labour Economics*, 2011
74. Gars, Johan, *Essays on the Microeconomics of Climate Change*, 2012
75. Spiro, Daniel, *Some Aspects of Resource and Behavioral Economics*, 2012
76. Ge, Jinfeng, *Essays on Macroeconomics and Political Economy*, 2012
77. Li, Yinan, *Institutions, Political Cycles and Corruption*, 2012
78. Håkanson, Christina, *Changes in Workplaces and Careers*, 2013
79. Qin, Bei, *Essays on Empirical Development and Political Economics*, 2013
80. Jia, Ruixue, *Essays on the Political Economics of China's Development*, 2013
81. Campa, Pamela, *Media Influence on Pollution and Gender Equality*, 2013
82. Seim, David, *Essays on Public, Political and Labor Economics*, 2013
83. Shifa, Abdulaziz B., *Essays on Growth, Political Economy and Development*, 2013
84. Panetti, Ettore, *Essays on the Economics of Banks and Markets*, 2013
85. Schmitt, Alex, *Beyond Pigou: Climate Change Mitigation, Policy Making and Decisions*, 2014
86. Rogall, Thorsten, *The Economics of Genocide and War*, 2015
87. Baltrunaite, Audinga, *Political Economics of Special Interests and Gender*, 2016

88. Harbo Hansen, Niels-Jakob, *Jobs, Unemployment, and Macroeconomic Transmission*, 2016
89. Stryjan, Miri, *Essays on Development Policy and the Political Economy of Conflict*, 2016
90. Karadja, Mounir, *On the Economics and Politics of Mobility*, 2016
91. Kitamura, Shuhei, *Land, Power and Technology, Essays on Political Economy and Historical Development*, 2016
92. Malmberg, Hannes, *Human Capital in Development Accounting and Other Essays in Economics*, 2017
93. Öberg, Erik, *On Money and Consumption*, 2017
94. Lane, Nathaniel, *States of Development: Essays on the Political Economy of Development in Asia*, 2017
95. Prawitz, Erik, *On the Move: Essays on the Economic and Political Development of Sweden*, 2017
96. Iwanowsky, Mathias, *Essays in Development and Political Economics*, 2018
97. Dehdari, Sirus Håfström, *Radical Right, Identity, and Retaliation*, 2018
98. Harmenberg, Karl, *Essays on Income Risk and Inequality*, 2018
99. Kilström, Matilda, *Households' Responses to Policy in Labor and Credit Markets*, 2018
100. Meriläinen, Jaakko, *Essays in Political Economics*, 2019
101. Sigurdsson, Jósef , *Essays on Labor Supply and Adjustment Frictions*, 2019
102. Coccio, Serena, *Participatory Governance and Public Service Provision* , 2019
103. Mitrunen, Matti, *Essays on the Political Economy of Development*, 2019
104. Olsson, Jonna, *Work, wealth, and well-being: Essays in macroeconomics*, 2019
105. Daroughch, Saman, *Search and Mismatch*, 2019

106. van Vlokhoven, Has, *On the Cost of Capital, Profits and the Diffusion of Ideas*, 2020
107. Foltyn, Richard, *Essays in Macroeconomics and Household Finance*, 2020
108. Lerva, Benedetta, *Worms, Farms and Schools: Three Essays on Investment Choices in Uganda*, 2020
109. Kragh-Sørensen, Kasper, *On Housing, Mortgages, and Taxation*, 2020

The thesis consists of three self contained essays

Costly reversals of bad policies: the case of the mortgage interest deduction studies how U.S. households are affected by removing the mortgage interest deduction, and how the welfare effects depend on the design of the removal policy.

Mortgage lending standards: implications for consumption dynamics investigates to what extent stricter mortgage regulations can dampen the fall in consumption during economic downturns.

The great house price divergence: a quantitative investigation of house price fundamentals studies the role of fundamentals in explaining the widening gap in house prices across U.S. metropolitan areas.

Markus Karlman

holds a BSc and MSc in Economics
from Stockholm University.

ISBN 978-91-7911-202-8
ISSN 0346-6892

Department of Economics

