Down-payment requirements: Implications for portfolio choice and consumption

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April 28, 2023

Abstract

This paper studies how down-payment requirements for house purchases affect households' portfolio choices, consumption, and responses to macroeconomic policy. We show that requiring households to invest more equity in the house actually reduces the willingness of young renters to save for the down payment. This increases the number of credit-constrained renters with high marginal propensities to consume (MPC). However, households also postpone purchasing a house, which reduces the number of homeowners with high MPCs. Using an incomplete-markets model, calibrated to the U.S. economy, we find that the two offsetting effects imply that stricter down-payment constraints have relatively small effects on mean MPC. Yet, we uncover substantial heterogeneous effects on households' portfolio choices and consumption, with significant implications for welfare and macroeconomic policy. Indeed, stricter requirements are associated with large welfare losses, reduced effectiveness of monetary policy, and it becomes increasingly important to direct fiscal transfers at low-income households.

Keywords: down-payment requirement, heterogeneous households, housing, life cycle, loan-to-value constraint, marginal propensity to consume

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[*]We are grateful for helpful discussions with John Hassler, Martin Holm, Per Krusell, Chloe Larkou, Ralph Luetticke, Kurt Mitman, Monika Piazzesi, Martin Schneider, Kjetil Storesletten, Karl Walentin, and seminar participants at Banque de France Conference on Household Heterogeneity, BI Norwegian Business School, CEPR WE_ARE Seminar Series, EEA 2022, Federal Reserve Bank of New York, Housing Lab at Oslo Metropolitan University, LMU Munich, Lund University, Macro-Workshop at University of St.Gallen, Norges Bank, Norwegian Ministry of Finance, Nordic Junior Macro Seminar Series, Oslo Macro Conference, Statistics Norway, Stellenbosch University, Stockholm University, University of Cape Town, University of Oslo, University of Pretoria, Yale University, and 5th Workshop of the Spanish Macroeconomics Network.

1 Introduction

How does the consumption and savings behavior of households depend on borrowing constraints? This is a key question in economics that has received considerable attention in the macroeconomic literature.[1] However, due to the historical importance of one-asset models, the literature has largely focused on constraints that limit the amount that households can borrow using unsecured credit.

Motivated by two recent developments, we revisit the question of how borrowing constraints affect households' behavior. First, there is a growing empirical and theoretical literature showing that households' savings in assets with various liquidity is important for understanding the distribution of marginal propensities to consume (MPCs). In particular, many relatively wealthy households that hold most of their wealth in illiquid assets and have low levels of liquid savings have high MPCs. These households are also found to play a fundamental role for understanding the transmission mechanisms of monetary and fiscal policy.[2] When considering assets with different liquidity, constraints on secured borrowing, where the illiquid asset is used as collateral, become relevant.

Second, there is a rapid increase in the share of countries that have implemented collateral constraints in the form of down-payment requirements for house purchases. Figure 1 shows that the fraction of advanced economies with such a requirement in place has increased from merely 6 percent in 1990 to over 60 percent in 2020 (Alam et al., 2019).[3] Moreover, the average down-payment requirement, among the countries that have implemented a constraint, has increased from approximately 3 percent to over 20 percent. As housing is the largest and most important illiquid asset for most households, the required down payments are often substantial and likely to affect households' consumption and savings behavior. Yet, at this point we do not have a profound understanding of how changes in the down-payment constraint impact households' savings and MPCs. In fact, even the sign of the effect on a household's MPC is not obvious.

The purpose of this paper is to fill some of this gap. How does the level of the down-payment requirement affect households' savings and portfolio choices of debt and housing wealth? What does it imply for their consumption choices in response to shocks or macroeconomic policies? To answer these questions, we first construct a stylized life-cycle model to highlight qualitatively how the down-payment constraint shapes household behavior. We then proceed by building a heterogeneous-household incomplete-markets

[1] Seminal papers include, but are not limited to, Bewley (1977), Deaton (1991), Krusell and Smith (1998), Schechtman (1976), and Scheinkman and Weiss (1986).

[2] See, e.g., Auclert et al. (2018) and Kaplan and Violante (2014) for the role of MPCs for fiscal policy and Auclert (2019) and Kaplan et al. (2018) for the role of MPCs for monetary policy.

[3] Figure 1 shows the share of countries with a loan-to-value requirement, which is equivalent to one minus the down-payment constraint, and the average constraint across these countries.

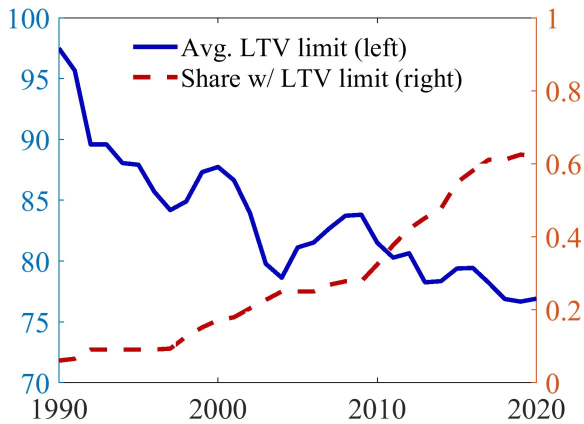


Figure 1: Prevalence of loan-to-value limits among advanced economies

Note: A loan-to-value requirement is equivalent to one minus the down-payment constraint. For example, a loan-to-value requirement of 80 percent is equivalent to a down-payment requirement of 20 percent. The data is for all advanced economies.

Source: The IMF's integrated Macroprudential Policy (iMaPP) Database, originally constructed by Alam et al. (2019).

model to quantitatively assess the implications of a stricter down-payment requirement in the U.S.

Our main results are as follows. First, we show that a stricter down-payment requirement significantly alters households' savings and portfolio choices over the life cycle. In particular, households find it optimal to delay homeownership and, in turn, also postpone when they start saving for the house. Hence, requiring households to save more to buy a house actually makes them save less.[4] Since there is a larger number of young renters with limited savings, there is an increase in the share of poor hand-to-mouth (HtM) households with high MPCs. However, since there are fewer young homeowners, there is also a reduction in the number of liquidity-constrained homeowners with high MPCs, i.e., the share of wealthy HtM households declines. Second, we find that although the distributional effects and welfare costs of stricter down-payment constraints are substantial, the mean MPC in the economy is relatively stable. This result follows from the two offsetting effects on the number of poor and wealthy HtM. However, the heterogeneous effects on households' portfolio choices have important implications for macroeconomic policy. In particular, we find that the cash-flow channel of monetary policy is reduced and fiscal transfers directed at households with low income are relatively more effective when the down-payment constraint is stricter.

We begin by developing a simple life-cycle model that captures the main features of a down-payment requirement. This model is a standard household problem of consumption

[4]We show analytically that this mechanism holds under standard assumptions.

and savings, appended with a traditional borrowing constraint as well as a down-payment constraint. The traditional borrowing limit restricts young households with relatively low earnings from fully smoothing consumption. These households have high MPCs and are so called poor HtM households. The down-payment constraint, on the other hand, specifies the savings required to receive utility benefits of homeownership. As such, it creates a trade-off: households with high enough income are willing to give up consumption in order to save to buy a house. Once the households have accumulated enough savings for the down payment, they become homeowners. At this point, the households save too much from a consumption-smoothing perspective, and hence, for some time, consume everything that they earn. Consequently, they respond strongly to any transfer and have high MPCs, despite having positive wealth. Hence, the model features both poor and wealthy HtM households, as described in Kaplan and Violante (2014), even though there is no illiquid asset.

The optimal timing of when the household starts to save for the house purchase is a function of when it is optimal to become a homeowner, which in turn depends on the size of the down payment. The benefits of starting to save are given by the added utility in all the future periods of being a homeowner, while the costs are given by the foregone consumption when saving for the down payment. It is optimal to start to save for the down payment as soon as the benefits exceed the costs. For any given time that a household starts to save, a stricter down-payment requirement makes it optimal to delay the house purchase, since more savings are needed. Hence, the benefits of saving are reduced, as the number of periods as homeowner declines. At the same time, the costs of saving increase due to larger deviations from consumption smoothing. Importantly, since earnings increase with age, the marginal cost of saving decreases over the life cycle. As a result, it is optimal to postpone saving for the down payment. Since young households save less, the number of poor HtM households increases. On the other hand, the delayed house purchase results in fewer homeowners and thereby fewer wealthy HtM households. Moreover, when the marginal house buyer is older, they are also less constrained by the down-payment requirement due to higher earnings and more savings for retirement.

As a stricter down-payment requirement reduces the share of wealthy HtM households, while it increases the share of poor HtM, the overall effect on mean MPC depends on the relative size of the two effects. At very low levels of the constraint, even the youngest people with the lowest earnings save for the down payment. A stricter constraint induces these households to save for a longer time before being able to buy the house, which decreases the share of wealthy HtM. However, they may still find it optimal to start to save for the down payment as early as possible, hence, it does not necessarily increase the number of poor HtM households. If the constraint, on the other hand, is tightened from a relatively high level, the share of potential wealthy HtM is already largely exhausted. Thus, there is a weaker downward effect on the average MPC. In contrast, the share of poor HtM households continues to rise as the stricter constraint keeps making it optimal to postpone the starting time of saving for the down payment. Taken together, the mean MPC is U-shaped in the down-payment requirement.

The simple model also highlights that there is an important interaction between secured and unsecured borrowing restrictions in determining households' MPC. Without a traditional borrowing constraint there would be no increase in the number of poor HtM households when the down-payment requirement is tightened. Consequently, in such a setting, a stricter down-payment constraint would weakly decrease mean MPC.

Although the simple model captures important mechanisms of households' consumption and savings choices, a richer heterogeneity is needed for a quantitative analysis of the effects of changing the down-payment requirement. In particular, earnings- and wealth heterogeneity and earnings risk are important elements needed to capture a realistic distribution of MPCs. We proceed by constructing a rich life-cycle model with heterogeneous households, where mortgage and housing markets are modeled in detail. Markets are incomplete as idiosyncratic earnings risk is not fully insurable. Households derive utility from non-durable consumption goods and housings services, where housing services can be obtained by either renting or owning a house. A household can save in liquid, risk-free bonds, and also in illiquid housing equity. There are transaction costs associated with both buying and selling a house, and there are down-payment and payment-to-income (PTI) constraints that limit the size of new mortgages. Finally, it is costly to use cash-out refinancing to access housing equity.

The model is calibrated to the U.S. economy and matches important features of the data, including the distributions of liquid savings-to-earnings, debt, housing wealth-to-earnings, as well as the life-cycle profile of homeownership. The model also produces a rich distribution of MPCs across households. Portfolio choices, both in terms of leverage, housing, and liquid bond holdings, play an important role in determining households' MPC. A significant portion of renters hold no or very little liquid savings and have high MPCs. Moreover, a substantial fraction of homeowners also have high MPCs as they have most of their wealth invested in illiquid housing. We furthermore validate our model by showing that the short-run effects of introducing a stricter down-payment requirement are qualitatively in line with the results in the empirical literature (see Aastveit et al. (2020) and Van Bekkum et al. (2019)).

Consistent with the simple life-cycle model, our quantitative model shows that the mean MPC is U-shaped in the down-payment requirement. Again, we see that households both postpone buying a house and delay when they start saving for the down payment, when the constraint is made stricter. This results in a reduction of the share of wealthy HtM households, and an increase in the share of poor HtM. The overall effect on mean MPC is relatively small and depends on which of the two effects dominate, which in turn depends on how strict the constraint is to begin with. The mean MPC is minimized at a down-payment constraint of approximately 40 percent, which is associated with a 5 percent reduction in the mean MPC from its current level.

While the effect on the average MPC is modest, we find that the significant distributional effects of changing the down-payment constraint have important implications for welfare and macroeconomic policy. Since many households are adjusting their savings and portfolio choices in response to a tighter constraint, the welfare costs of the households are considerable. High-earning households are particularly affected, since they tend to buy a house when they are fairly young and when their income profile is steep. As a result, additional savings is relatively costly in utility terms. We also find that a stricter down-payment constraint dampens the mortgage cash-flow channel of monetary policy, since it decreases the mortgage balance among the liquidity-constrained households, making monetary policy less potent. In terms of fiscal policy, we see that although transfers to low-income households are always the most effective, a stricter down-payment requirement makes it relatively more important to target these households. This follows from our finding that low-income households' MPCs increase with a stricter constraint, whereas the MPCs among high-income households decrease on average.

Previous literature. This paper relates to two broad strands of literature. First, we relate to the literature on borrowing constraints and how these affect households' savings behavior. Second, we speak to the literature on heterogeneity in MPCs and its consequences for fiscal and monetary policy. Specifically, we merge these two literatures by analyzing the long-run effects of changes in the down-payment constraint for different households' consumption, savings and portfolio choices, and the implications for macroeconomic policy.

In terms of the literature on borrowing constraints, a number of papers use theoretical models to explain how down-payment requirements affect household behavior. Artle and Varaiya (1978) and Slemrod (1982) study simple life-cycle models where households can choose between becoming a homeowner or rent throughout their life. They show that households who decide to become a homeowner save more when they are young. Thus, as in our model, households need to trade off consumption when young against the benefit of homeownership when older. We complement their analysis by, e.g., allowing households to also choose the timing of house purchases, which has important implications for savings dynamics and policy. Moreover, we show that the mechanisms hold in a simple analytical framework as well as in a large-scale model of the U.S. economy. Stein (1995) and Ortalo-Magne and Rady (2006) study the role of down-payment requirements in explaining, e.g., house price and transaction volume variability. In their framework, repeated home buyers play a central role, as falling house prices may reduce homeowners' housing equity and thus their possibility to buy another home. Chambers et al. (2009) show that a relaxation of down-payment constraints, especially among young households, was important for the increase in the homeownership rate between 1994 and 2005. In line with this result, we find that stricter down-payment requirements make some households buy their first home later, and we then investigate the implications of this for households' MPCs. Greenwald (2018) finds that PTI requirements are more effective than LTV limits in counteracting cyclicality, and highlights their role in the Great Recession. Our focus is instead on the long-term effects of changes to the down-payment constraint and our model includes a richer heterogeneity among households, which allows us to explore differences in consumption responses across households.

There is also an empirical literature on down-payment constraints. Engelhardt (1996) shows that most households save for the down payment themselves and are constrained by the requirement. Fuster and Zafar (2016) provide survey evidence that households' intention to buy a house is sensitive to the down-payment requirement. A number of papers study down-payment constraints in the context of business-cycle analysis (see, e.g., Acharya et al. (2022); Lim et al. (2011); Peydro et al. (2020)). Aastveit et al. (2020) and Van Bekkum et al. (2019) study the effects of stricter LTV limits on households' portfolio choices in Norway and the Netherlands, respectively. They find that stricter LTV requirements are associated with lower house purchase probabilities and debt levels, but also liquid savings, making the effect on financial vulnerability uncertain. Aastveit et al. (2020) and Van Bekkum et al. (2019) offer valuable empirical evidence of how LTV requirements affect marginal home buyers in the short and medium run. We therefore use their results to validate our quantitative model. Our findings of the short-run effects of stricter down-payment constraints are qualitatively in line with their results. Our paper then complements their analysis by focusing on the long-run consequences of down-payment constraints and by showing how the entire distribution of households are affected by such policies. We highlight that a down-payment requirement has important implications for the savings behavior of households that are not directly affected by the constraint.

In the literature on households' MPCs, most empirical studies show that MPCs tend to be much higher than the permanent income hypothesis suggests.[5] Not only do MPCs tend to be high, but they also vary substantially across the population depending on households' balance sheets.[6] In their seminal work, Kaplan and Violante (2014) show that

[5]See Jappelli and Pistaferri (2010) for a review of the earlier literature.

[6]See, e.g., Agarwal and Qian (2014); Broda and Parker (2014); Cloyne et al. (2019); Cloyne and Surico (2017); Fagereng et al. (2021); Misra and Surico (2014); Parker et al. (2013); and Carroll et al. (2014) for

when incorporating an illiquid asset in a heterogeneous agent model, wealthy households can also have high MPCs, as observed in the data. Kaplan et al. (2018) build on this insight and show that because a large fraction of households are constrained, indirect effects of monetary policy become substantially more important than in representative agent models. In Auclert et al. (2018), the distribution of MPCs across households and time are key for understanding the size of fiscal multipliers. We focus our attention on one specific type of illiquid asset, housing, and construct a model with detailed housing and mortgage markets to consider how changes in the down-payment requirement affect the distribution of MPCs and its implications for policy.[7]

In studying the implications for macroeconomic policy, we contribute to three separate branches of the literature. First, the importance of the cash-flow channel of monetary policy has been studied in several papers, see, e.g., Calza et al. (2013), Cloyne et al. (2019), Di Maggio et al. (2017), Flodén et al. (2020), Guren et al. (2021), Holm et al. (2021), Kinnerud (2022), and Verner and Gyöngyösi (2020). We emphasize that the aggregate effect of changes in cash flows from monetary policy decreases with the level of the down-payment requirement. Second, there are a number of papers that consider macroprudential policies and their interactions with monetary policy, of which Angelini et al. (2012) provide a review. We show that in the long run there is a trade-off: introducing a stricter down-payment requirement can lower the mean MPC in the economy, but it also dampens the direct cash-flow channel of monetary policy. Finally, Kaplan and Violante (2014) and Jappelli and Pistaferri (2014) study alternative cash-transfer schemes and consider how these should be designed to offer the most "bang for the buck". Using this perspective, we show that a larger share of transfers should be allocated to low-income households when the down-payment constraint is stricter.

The remainder of the paper is organized as follows. In Section 2, we develop a theoretical framework to analyze how changes in the down-payment constraint affect different households' savings choices and MPC. In Section 3, we proceed by constructing a model of the U.S. economy. The model is then calibrated in Section 4. Here, we also compare the performance of the model to the data and validate the model against the empirical findings of the short-run effects of stricter down-payment requirements. Section 5 presents the main quantitative results and Section 6 concludes the paper.

a theoretical investigation.

[7] Boar et al. (2021) provide a thorough analysis of the constraints in the U.S. housing market, which contribute to the illiquid nature of housing equity, and study mortgage forbearance policies.

2 Down-payment requirements in a simple framework

Before we turn to a quantitative analysis where the housing and mortgage markets are modeled explicitly, this section studies a simple extension of a standard consumption-savings problem. We use this simplified framework to illustrate how households' savings choices are affected by a down-payment constraint, and in turn, what this implies for MPCs.

2.1 A simple life-cycle model with a down-payment requirement

Consider a stylized life-cycle model with one representative household per age j.[8] Households are born at age 23, work until age 64, and die with certainty at age 83. It is an endowment economy where households face an upward-sloping earnings profile, and receive benefits during retirement. The age-dependent income is the only source of heterogeneity in the model. For simplicity, and to roughly mimic a typical earnings profile from the data, we assume that earnings grow linearly and are doubled during working age. The replacement rate during retirement is set to one half of earnings in the period before retirement, and the mean income is normalized to one.

In each period, households choose consumption c, savings in risk-free liquid bonds b', and housing h', where $h' = 0$ represents renting, and $h' = \bar{h} > 0$ represents owning. We add two constraints to this problem. The first is a classic borrowing limit that we set to zero, i.e., $b' \geq \underline{\mathrm{b}} = 0$. The second is the down-payment requirement $\theta h'$, which requires households to finance a share θ of the house value with own savings, i.e., $-b' \leq (1-\theta)h'$.

Households derive utility from consumption and owned housing. To simplify the notion of homeownership, the utility from homeownership is included as a utility bonus Ψ, which is additively separable from the utility from consumption, an assumption that we relax in the quantitative model in the next section.[9] For simplicity, we also assume that households do not discount the future ($\beta = 1$), the interest rate on savings in risk-free bonds is zero ($r = 0$), and households have log preferences over consumption.[10] The households' dynamic problem is characterized by

[8]In Appendix A.1, we describe a two-period model. While a two-period model can capture that a stricter down-payment constraint causes some households' MPC to increase and others' to decrease, it does not include the timing effects that we find to be crucial in the more realistic life-cycle setting.

[9]It is common in the literature to assume that owned housing is associated with higher utility than rental housing.

[10]This model set-up is isomorphic to a model where housing is not explicitly included, but where the down-payment constraint is simply a savings threshold for receiving a utility bonus. We outline this comparable model in Appendix A.2.

$$
\begin{aligned}
V_j(x) = \max_{c,b',h'} U(c,h') &+ V_{j+1}(x') \; s.t. \\
h' &\in \{0, \bar{h}\} \\
c = x - b' - h' & \qquad \text{Budget constraint} \\
x' = y' + b' + h' & \qquad \text{Law of motion cash-on-hand} \\
b' \geq 0 & \qquad \text{if } h' = 0 \\
-b' \leq (1-\theta)h' & \qquad \text{if } h' = 1 \\
U(c,h') = \log(c) + h'\Psi, &
\end{aligned}
$$

where y is earnings and x is the state variable cash-on-hand.[11]

If there were no financial constraints in the model, households would consume the same in every period. However, the two constraints that limit borrowing can cause households to deviate from perfect consumption smoothing. The traditional borrowing limit prevents households from borrowing against future income, which results in lower consumption than preferred early in life when labor income is the lowest. The down-payment constraint, on the other hand, creates a tradeoff for the households. The earlier a household starts to save for the down payment, the sooner will the household reap the benefits of homeownership. However, saving early in life, when income is relatively low, comes at the cost of deviations from perfect consumption smoothing.

The importance of the two constraints varies over the life cycle, as illustrated by the solid lines in Figure 2a, 2b, and 2c, which depict the life-cycle profiles of net worth, consumption, and MPCs in our baseline parameterization. For young households, with relatively low income, the traditional borrowing limit is binding. They save nothing and consume all that they earn, resulting in a hand-to-mouth (HtM) behavior and an MPC of one.

As households age and income rises, the utility cost of cutting back on consumption decreases, making it worthwhile to save for the down payment. During the periods that households save for the down payment, their consumption profile is flat (in the given parametrization), and they are unconstrained renters with relatively low MPCs.

Once the savings reach the required down payment, households become homeowners, and any further savings are driven by the desire to save for retirement. Since the households have already saved a substantial amount to become homeowners, for some time, they do not increase savings further and instead consume all their income. Therefore, despite having positive wealth, these homeowners have an MPC of one and are classified as wealthy HtM

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

households.[12] As earnings continue to increase, households' optimal savings eventually exceed the down-payment requirement, and they become unconstrained owners.[13]

Equipped with this framework, we now analyze how changes to the down-payment constraint impact households' savings behavior, the shares of poor and wealthy HtM households, as well as distributional and aggregate MPC.

2.2 How does a larger down-payment constraint affect savings?

The dashed lines in Figure 2a, 2b, and 2c illustrate how the life-cycle patterns of savings, consumption, and MPCs change when the down-payment constraint is made stricter. Compared to the baseline economy, households delay their savings for the down payment and become homeowners at a later point in life. Consequently, the time spent as a poor HtM household increases, while the time spent as a wealthy HtM household decreases.

To understand the underlying mechanisms behind these results, it is useful to consider how households decide on the optimal time to start saving for a house and how this decision relates to the timing of the home purchase. On the one hand, the earlier households start to save for the down payment, the sooner and longer they can enjoy the benefits of being a homeowner. On the other hand, the earlier they start to save, the higher is the cost of foregoing consumption, as income is increasing over time. The optimal time to start saving is as soon as the benefits exceed the costs. Once households start saving, the time it takes to accumulate enough savings to become a homeowner depends on two factors: the steepness of the income profile, which determines how quickly households save, and the size of the down-payment requirement, which specifies the needed amount.

When the down-payment constraint is increased, households spend a longer time accumulating savings for any given time they start to save. This prolonged time of saving means that households spend less time as homeowners. As a result, the benefits of saving for the down payment decrease, and it is no longer optimal to start saving as early as before. Instead, households delay their savings to periods in life where income is higher, and consequently, it is less costly to reduce consumption.[14]

Households' responses to the higher down-payment constraint have two key implications. First, although a higher down-payment constraint requires households to save more to become homeowners, young households still choose to save less, resulting in an increase in the share of poor HtM households. Second, as households postpone homeownership, the

[12] Notably, even if there are no transaction costs in the model, the presence of a down-payment constraint, along with the extra utility obtained from homeownership, is enough to generate wealthy HtM behavior.

[13] In this simple model, there is no bequest motive. Hence, the MPC increases when households approach the end of life.

[14] The intuition is laid out in more detail in Appendix A.3, where we characterize the cost-benefit tradeoff and show an analytical derivation of the postponement response.

share of wealthy HtM households decreases as there are fewer young homeowners and the time it takes for homeowners' optimal savings for retirement to exceed the down payment is shorter.

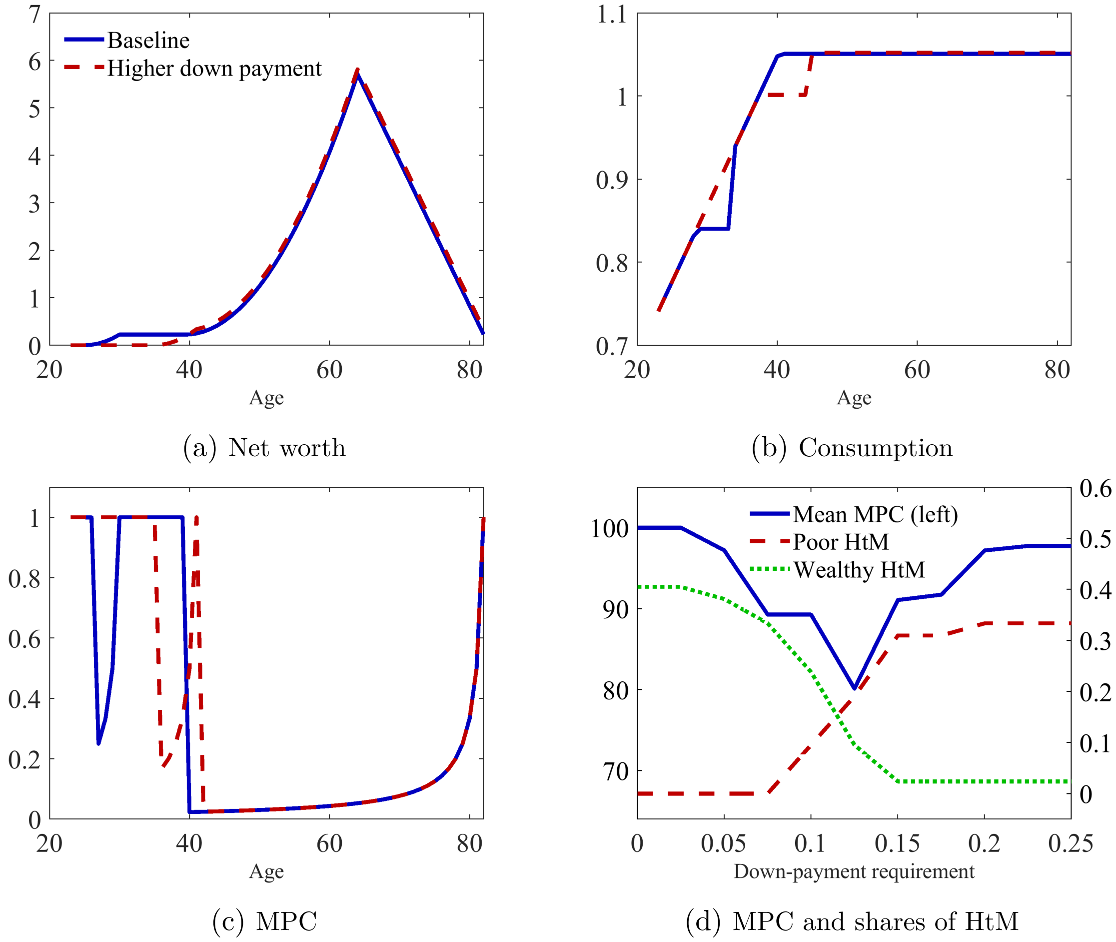


Figure 2: Life-cycle profiles in a stylized model, and mean MPC and shares of wealthy and poor hand-to-mouth households across a range of down-payment requirements.

Figure 2d demonstrates the effects of a wide range of down-payment constraints on the mean MPC in the economy and the shares of poor and wealthy HtM households. A key finding from this figure is the U-shaped relationship between the mean MPC and the down-payment constraint.

At very low levels of the constraint, all households find it worthwhile to save for the down payment. A stricter constraint causes households to postpone the house purchase, which reduces the share of wealthy HtM households. However, the benefits of saving for the down payment may still exceed the costs for all households. Therefore, the decline in the share of wealthy HtM households dominates the effect on the poor HtM at low values of the down-payment constraint, causing the mean MPC to fall.

As the down-payment constraint becomes stricter, the share of wealthy HtM households continues to decrease. Further postponements of homeownership make it less appealing for young households with relatively low earnings to save for the down payment, as the benefits of saving decrease, which results in an increase in the share of poor HtM households. This increase in the fraction of poor HtM households dampens the fall in the mean MPC.

When the constraint is tightened further, the wealthy HtM households become more and more depleted, while the number of poor HtM households continues to rise. Thus, when the constraint is already relatively high, the rise in the share of poor HtM households dominates the effect on the wealthy HtM, leading to an increase in the mean MPC. The mean MPC therefore follows a U-shaped pattern in the down-payment constraint, as the decline in the share of wealthy HtM households is relatively more pronounced at low levels of the constraint, while the increase in the share of poor HtM households is relatively more prominent at high levels of the constraint.

This analysis also uncovers an interesting interaction between the down-payment requirement and the standard borrowing constraint in determining households' MPCs, and of which the U-shape in the mean MPC is a direct result of. When the down-payment constraint increases, some young households opt to not save for housing purposes. In the presence of a borrowing constraint, these households become poor HtM households with high MPCs. However, in the absence of a borrowing constraint, these households would instead borrow against future income, becoming unconstrained renters with low MPCs. Thus, it is important to study changes to the down-payment requirement alongside relevant constraints on unsecured borrowing.

2.3 How general are these results?

After exploring the optimal behavior of households to changes in the down-payment constraint, the question arises as to how general these results are. To address this question, and to show analytically under what conditions our results hold, we construct a simplified version of the model in the previous section, reformulated in continuous time. This analysis is presented in Appendix A.3, and the main results are summarized here.

By using a continuous-time model, we can analytically demonstrate the sufficient conditions for the two key mechanisms of our main results, namely, that households delay their savings and postpone their housing purchase when the down-payment constraint is increased. We show that the standard assumptions of a concave utility function of consumption and an increasing and non-convex income profile are sufficient for these results to hold.[15] Thus, households' responses to stricter down-payment constraints hold

[15]It is possible to find cases where the results hold even with a convex income profile. In Appendix A.3, we consider a case with log utility of consumption and an exponential income profile, and we provide

in many diverse economic environments.

Still, there are some features of the simple model that, when relaxed, may impact the strength of the mechanisms previously described. First, there is only one house size available in the simple framework. Since our analysis highlights that a stricter down-payment requirement affects the extensive-margin decision of when to buy a house, a stricter constraint may also affect the intensive margin, i.e., the optimal house size. Second, there is no earnings risk in the simple model. With earnings risk, households hold precautionary savings, which impacts MPCs. Third, the illiquid nature of houses and mortgages need to be included. Houses are costly to buy and sell, cash-out refinancing is not always possible, and mortgages are typically long-term contracts with pre-specified repayment plans. Finally, since the effect on mean MPC depends on how the shares of poor and wealthy HtM households are affected by the down payment, it is important to capture the prevalence of these different types of households in the economy. Hence, a quantitative analysis of the effects of a stricter down-payment constraint requires a richer model that captures household heterogeneity and financial and housing markets in a realistic way.

3 A model of the U.S. economy

To quantify how changes in the down-payment requirement affect households' savings, portfolio, and consumption choices, we build a heterogeneous-household model with incomplete markets, where the mortgage and housing markets are modeled explicitly. 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, when taking up a new mortgage households face a down-payment requirement, which is equivalent to one minus a loan-to-value (LTV) constraint. To further capture the constraints in the U.S. housing market, households also have to comply with a payment-to-income (PTI) requirement, and 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. In the benchmark analysis we assume that aggregate housing supply is also fully elastic in the long run, which implies that house prices are unaffected by changes to the down-payment constraint. In Appendix E.2 we show that the main results do not

a closed-form solution showing that households postpone both their savings and their house purchase.

depend on this assumption. Housing consists of both owned and rental housing units that are available in discrete sizes. 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.[16]

3.1 Households

Demographics. The model is a life-cycle model with overlapping generations. Households enter the economy at age $j = 1$ and work until they retire at age J_{ret}. There is a unit measure of households at each of these ages. During retirement households face an age-dependent probability of surviving to the next period $\phi_j \in [0, 1]$, where $\phi_J = 0$.

Idiosyncratic earnings. The labor income process is inspired by Cocco et al. (2005). There is an age-dependent and a household-specific component of earnings. Throughout their lives, households are subject to idiosyncratic earnings risk. Households of working age face both permanent and transitory risk. 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.

More specifically, log earnings for a working-age household i of age j are given by

$$\log(y_{ij}) = \alpha_i + g(j) + n_{ij} + \nu_i \quad \text{for } j \leq J_{ret}, \tag{1}$$

where α_i is the household fixed effect, distributed $N(0, \sigma^2_\alpha)$, 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 $N(0, \sigma^2_\eta)$. The household also draws an i.i.d. transitory shock ν_i, distributed $N(0, \sigma^2_\nu)$, 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}. Further, the benefits are affected by transitory shocks, drawn from the same distribution as the transitory earnings shocks. Formally,

$$\log(y_{ij}) = \min\left(\log(R) + \log(z_{i,J_{ret}}),\ \log(B^{max})\right) + \nu_i \quad \text{for } j > J_{ret}. \tag{2}$$

Assets and mortgages. Households enter the economy with different levels of initial

[16] Overall, the model shares many features with the model in Karlman et al. (2021).

net worth. The distribution of net worth among the entering cohort is matched to the data, as in Kaplan and Violante (2014).

The housing stock is fully elastic and it is flexible in its composition of rental housing and owned housing. There is a set of discrete house sizes available for rent $S = \{\underline{s}, s_2, s_3, ..., \bar{s}\}$. The sizes available for ownership constitute a proper subset H of those available for rent. Specifically, the smallest housing size available for purchase is larger than the smallest size available for rent.[17] There are transaction costs associated with both 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' at an interest rate r^m. 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 the outstanding mortgage balance that needs to be paid by a household of age j, where

$$\chi_j = \left(\sum_{k=1}^{M_j} \left[\frac{1}{(1+r_m)^k} \right] \right)^{-1}. \tag{3}$$

M_j denotes the maturity of the mortgage. To mimic the most commonly used mortgage contract in the U.S., the 30-year fixed-payment mortgage, the maturity is set to $M_j = \min\{30, J - j\}$. This specification stipulates that the repayment period cannot extend beyond the age of certain death, thus capturing the fact that older people tend not to take up long-term mortgages. A household that wishes to deviate from the minimum-payment schedule provided in equation (3) can use cash-out refinancing by paying a fixed cost ς^r.

The use of mortgage financing is further limited by the PTI constraint and the down-payment requirement. 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 down-payment requirement is a fraction θ of the house value. Thus, the amount of housing equity needed to abide with the down-payment constraint can be stated as follows

$$p_h h' - m' \geq \theta p_h h'. \tag{4}$$

The down-payment requirement can equivalently be written as an LTV constraint. In that case, the maximum allowable mortgage is a share $1-\theta$ of the house value: $m' \leq (1-\theta) p_h h'$. The PTI constraint, on the other hand, restricts the use of a mortgage by specifying

[17]It is common in the literature to have a limit on the smallest size available for purchase; see for example Cho and Francis (2011), Floetotto et al. (2016), Gervais (2002), and Sommer and Sullivan (2018).

that housing-related payments, including mortgage payments, cannot exceed a share ψ of current permanent earnings z,

$$\chi_{j+1} m' + (\tau^h + \varsigma^I) p_h h' \leq \psi z. \tag{5}$$

The housing-related payments also include property taxes τ^h, and home insurance payments ς^I, both proportional to the house value.[18]

Households have two ways of saving in the model. One way to save is to increase housing equity, i.e., owner-occupied housing net of mortgages. The other way to save is to buy risk-free bonds b', which yield a return r that is strictly lower than the mortgage interest rate r^m. Since housing equity is relatively illiquid, homeowners may still want to save in liquid bonds for precautionary reasons.

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

$$U_j(c, s) = e_j \frac{\left(c^\alpha s^{1-\alpha}\right)^{1-\sigma}}{1-\sigma}, \tag{6}$$

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)). Non-durable consumption is the numeraire good in the model. There is a linear technology that transforms owned housing units h' to housing services s, such that $s = (1 + \Psi)h'$ if $h' > 0$. Thus, owned housing translates into more housing services than the equivalent rental housing unit provides. The added service given by Ψ represents the additional utility that households derive from ownership. Moreover, homeowners enjoy the full housing services provided by their house and are not allowed to rent out part of their property.

We also include a warm-glow bequest motive for households in retirement. The utility from bequests is given by

$$U^B(q') = \upsilon \frac{\left(q'\right)^{1-\sigma}}{1-\sigma} \quad \text{for } j \in [J_{ret}, J], \tag{7}$$

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

$$q' = \frac{b' + p_h h' - m'}{\alpha + (1-\alpha)p_h}. \tag{8}$$

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

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

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

$$\Gamma \equiv \mathbb{I}^w \tau^{ss} y + \tau^h p_h h + T(\tilde{y}), \tag{9}$$

where the social security tax is paid only by the working age population, as indicated by the dummy variable $\mathbb{I}^w$. The labor income tax is modeled by the progressive tax and transfer function $T(\tilde{y})$, which takes taxable labor income after deductions $\tilde{y}$ as its argument. For a richer description of the tax system, see Section 3.3.

Household problem. 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

$$x \equiv \begin{cases} (1+r)b - (1+r^m)m + y - \Gamma - \delta^h h + (1-\varsigma^s)p_h h & \text{if } j > 1 \\ y - \Gamma + a & \text{if } j = 1, \end{cases} \tag{10}$$

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.

To solve the household problem, we compute the value function in each period separately for four mutually-exclusive discrete cases related to the housing and mortgage choice of the household. A household can choose to rent a house (R), buy a home (B), stay in an owned house that they enter 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 discrete case that yields the highest value. The renter case is characterized by the household choosing not to own a house; hence, mortgage financing is not allowed, 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 refinancer cases, the household chooses to stay in the owned house they enter the period with, i.e., $h' = h$.

For each $k \in \{R, B, S, RF\}$, the household problem is characterized by the following Bellman equation, where β is the discount factor, and the set of constraints listed below. Formally,

$$V_j^k(z,x,h,m) = \max_{c,s,h',m',b'} U_j(c,s) + \beta W_{j+1}(z',x',h',m')$$

where

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

subject to

$$\underbrace{c + b' + \mathbb{I}^R p_r s + \mathbb{I}^B (1+\varsigma^b) p_h h' + \mathbb{I}^{RF,S}(1-\varsigma^s) p_h h + \mathbb{I}^{RF}\varsigma^r}_{\text{“Expenditures”}} \leq \underbrace{x + m'}_{\text{“Money to spend”}} \tag{11}$$

$$\begin{aligned}
& p_h h' - \mathbb{I}^{B,RF} m' \geq \theta p_h h' && \text{Down-payment constraint} \\
& \mathbb{I}^{B,RF}\left(\frac{\chi_{j+1} m' + (\tau^h + \varsigma^I) p_h h'}{z}\right) \leq \psi && \text{PTI constraint} \\
& \mathbb{I}^S m' \leq (1+r_m) m - \chi_j m && \text{Min payment} \\
& s = (1+\Psi) h' && \text{if } h' > 0 \\
& m' \geq 0 && \text{if } h' > 0 \\
& m' = 0 && \text{if } h' = 0 \\
& c > 0, s \in S, h' \in H, b' \geq 0. &&
\end{aligned}$$

Equation (11) states the household's budget constraint. The variables $\mathbb{I}^k$ are indicator variables that equal one for the relevant 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 house buyers and households who refinance their mortgage have to comply with the down-payment and PTI requirements, while other homeowners have to adhere to the minimum-payment requirement of the amortization schedule. The solution to the household problem is given by

$$\begin{aligned} V_j(z,x,h,m) = \max \Big\{ & V_j^R(z,x,h,m), V_j^B(z,x,h,m) \\ & V_j^S(z,x,h,m), V_j^{RF}(z,x,h,m) \Big\}, \end{aligned} \tag{12}$$

with the policy functions that maximize the Bellman equation for the chosen discrete case

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

3.2 Rental market

There is a unit mass of homogeneous rental firms f that operate in a competitive market with free entry and exit. Rental firms offer rental housing to households, and are owned by foreign investors. The required rate of return of the investors is equal to the return on risk-free bonds r. The competitive rental rate p_r for a unit of rental housing is given by the user-cost formula,

$$p_r = \frac{1}{1+r}\Big[rp_h + \delta^r + \tau^h p_h\Big]. \tag{13}$$

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 $\tau^h p_h$.[19] Since the operating expenses are realized in the next period, these costs are discounted at the required rate of return of the investors.

3.3 Government

The role of the government in the model is to tax households and rental firms, and provide social security benefits to retirees. 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 (9). The labor income tax is modeled using a non-linear tax and transfer function $T(\tilde{y})$, as in Heathcote et al. (2017). This function is continuous and convex, and is meant to proxy for the progressive federal earnings taxes in the U.S.

$$T(\tilde{y}) = \tilde{y} - \lambda \tilde{y}^{1-\tau^p}, \tag{14}$$

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 deductible, and labor income after deductions is subject to a progressive tax schedule.

4 Calibration

We calibrate the model 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

[19]The assumption that rental property requires higher maintenance costs than owned housing is motivated by the potential moral-hazard problem of rental housing. This is also a common feature of housing models to generate a benefit of owning as compared to renting a house (see, e.g., Piazzesi and Schneider (2016)).

moments. It is in general difficult for this class of models to match the strong skewness in wealth that we observe in the data, we therefore choose to focus on the bottom 90 percent of the population in terms of net worth. The savings and consumption choices of the very wealthy individuals presumably do not depend much on the down-payment requirement, thus, restricting our attention to the bottom 90 percent should not materially affect our findings.

4.1 Independently calibrated parameters

Most of the parameters are calibrated independently, either computed from the data or taken directly from other studies. These parameters are listed in Table 1. In the next section, we move on to calibrate the remaining parameters internally by matching model moments to their data counterparts.

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	0.04
θ	Down-payment requirement	0.10
ψ	Payment-to-income requirement	0.177
δ^h	Depreciation, owner-occupied housing	0.03
ς^I	Home insurance	0.005
ς^b	Transaction cost if buying house	0.025
ς^s	Transaction cost if selling house	0.07
R	Replacement rate for retirees	0.5
B^{max}	Maximum benefit during retirement	61.5

Table 1: Independently calibrated parameters, taken from the data and other studies
Note: Where relevant, the parameter values are annual. The maximum benefit during retirement B^{max} is stated in 1000's of 2019 dollars.

Demographics. Households enter the model economy at age 23. At age 65, all households retire, and by age 83 all households have exited the economy. Before retirement, households do not face a risk of dying, but in between age 65 and 82 the probability of surviving to the next period ϕ_j is taken from the Life Tables for the U.S., social security area 1900-2100, for males born in 1950 (see Bell and Miller (2005)).

Idiosyncratic earnings. To estimate the earnings process in equation (1), we use data from the Panel Study of Income Dynamics (PSID), survey years 1970 to 1992. In the estimation of the age-dependent components of earnings $g(j)$, we follow Cocco et al. (2005).[20] We estimate the variances of the permanent and transitory shocks as in Carroll and Samwick (1997). The variance of the fixed-effect shock is estimated as the residual variance in earnings of the youngest cohort, net the deterministic trend value and the variances of the permanent and the transitory shocks. The estimated variances of the earnings shocks are displayed in Table 2. To estimate the retirement benefits in equation (2), we take the common replacement rate R from Díaz and Luengo-Prado (2008) and set it to 50 percent, and we compute B^{max} based on data from the Social Security Administration.

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

Table 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.

Assets and mortgages. 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 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 2019 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 2019 dollars. Within each earnings bin, we 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 then rescale by median earnings in the model when we allocate the initial assets to households in the model economy.

Using yearly data from 1989 to 2019 on 3-month Treasury bill rates, deflated by the Consumer Price Index (CPI), the mean real rate is 0.45 percent.[21] The interest rate on risk-free bonds is therefore set to zero. The average real interest rate on long-term

[20]The estimation of the earnings process is described in detail in Appendix D. Moreover, a robustness exercise with respect to the earnings process is performed in Appendix E.5.

[21]We use data from the Federal Reserve Bank of St Louis of the 3-month Treasury bill rate from the secondary market, not seasonally adjusted, and the CPI data is the U.S. city average CPI for all urban consumers, all items.

mortgages for the same period is equal to 3.9 percent. This is computed from the Federal Reserve's series of the average contract rate on 30-year fixed-rate mortgage commitments, deflated by the CPI. Hence, we choose a yearly mortgage interest rate of 4 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. In Appendix E.6, we show that our main results remain if we instead set the down-payment requirement to 20 percent in the baseline calibration. The payment-to-income requirement ψ is set to 0.177, which is consistent with the level in Greenwald (2018), but where we adjust for that the mortgage interest rate in our model is real. 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 in line with the median property insurance payment in the 2013 American Housing Survey (AHS).

Preferences. The coefficient of relative risk aversion σ in the utility function is set to 2, in line with much of the literature. The age-dependent utility shifter e_j, which captures how household size changes with the life cycle, is calibrated from the PSID, survey years 1970 to 1992. Specifically, we calibrate e_j using a regression of family size on a third-order polynomial of age, and then take the square root of the predicted values.

Taxes. Based on Harris (2005), the social security tax τ^{ss} is set to 15.3 percent of earnings, which corresponds to the total payroll tax for both employers and employees. The property tax rate τ^h is taken from the 2009, 2011, and 2013 waves of the AHS. The median real estate tax as a share of the housing value is approximately 1 percent.

4.2 Internally calibrated parameters

The parameters that are calibrated to match a set of data moments are listed in Table 3. Unless otherwise noted, we use data from the SCF, pooled across the 1989 to 2019 survey years. All parameters in Table 3 are jointly calibrated, taking the independently calibrated parameters in Table 1 as given.[22]

[22] When we solve the baseline model, the housing supply is chosen such that the price of a unit of owned housing is equal to the price of a unit of consumption, i.e., $p_h = 1$. In turn, the rental rate is given by equation (13). See Appendix B and C for a detailed description of the equilibrium definition and the solution method.

Parameter	Description	Value	Target moment	Data	Model
α	Consumption weight in utility	0.764	Median house value-to-earnings, age 23–64	2.29	2.29
β	Discount factor	0.953	Mean net worth, over mean earnings age 23–64	1.40	1.44
υ	Strength of bequest motive	4.2	Median net worth age 75 over median net worth age 50	1.67	1.59
Ψ	Utility bonus of owning	0.30	Mean own-to-rent size	1.80	1.83
δ^r	Depreciation rate, rentals	0.056	Homeownership rate, age 30–40	0.58	0.58
$\underline{\mathrm{h}}$	Minimum owned house size	180	Homeownership rate, all ages	0.67	0.67
ς^r	Refinancing cost	2.53	Refinancing share, homeowners	0.08	0.08
λ	Level parameter, tax system	1.698	Average marginal tax rates	0.13	0.13
τ^p	Progressivity parameter	0.142	Distribution of marginal tax rates	N.A.	N.A.

Table 3: Internally calibrated parameters

Note: Parameters calibrated to match model moments to their counterparts in the data. The first two columns list the parameters and their descriptions. The third column shows the calibrated parameter values. The fourth column contains the descriptions of the targeted moments, while column five lists their respective values in the data. Finally, the last column states the values of the corresponding model moments, achieved by using the parameter values in column three. The minimum owned house size $\underline{\mathrm{h}}$ and the fixed refinancing cost ς^r are in 1000's of 2019 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 0.764 to match the median house value-to-earnings ratio, among the working-age homeowners. The discount factor β affects the savings decisions. It is therefore used to match the mean net worth over mean earnings, among households of age 23 to 64. The resulting yearly discount factor is 0.953. To capture the strength of the bequest motive, the utility shifter of bequests υ is used to match the median net worth of households aged 75 over the median net worth of households aged 50. The parameter value is calibrated to be 4.2.

The decision to buy a house instead of renting housing services is affected by a number of factors in the model. Households generally prefer to own, however, frictions in the mortgage and housing markets stop some households from doing so. The positive net benefit of owning is due to the utility bonus of owning, the lower depreciation rate of owned housing, as well as the preferential tax treatment of housing and mortgage, i.e., mortgage interest payments and property taxes are deductible and imputed rents are left untaxed. The utility bonus of owning Ψ impacts the timing of the first house purchase, which in turn affects the average size of owned housing relative to rented housing. The utility bonus is calibrated to be 0.3. The higher depreciation rate of rental housing also incentivizes households to buy when they are younger. Therefore, we calibrate the depreciation rate of rental housing δ^r to match the homeownership rate among the relatively young households, aged 30 to 40. The minimum house size available for purchase $\underline{\mathrm{h}}$, which is strictly larger than the minimum house size available for rent, is set to match the overall homeownership rate in the data. To capture the liquidity of housing equity, we calibrate the fixed refinancing cost ς^r. With a cost of approximately 2530 in 2019 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 calibrated to match the level and the progressivity of earnings taxes in the U.S. The level parameter λ is set to 1.6975, 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 0.142, to minimize the sum of the absolute difference between the fraction of households exposed to the different statutory tax brackets in the data compared to the model. Since the tax schedule is continuous in the model, households are allocated to their nearest tax bracket in the data for this calibration exercise. The data on tax rates is taken from Harris (2005).

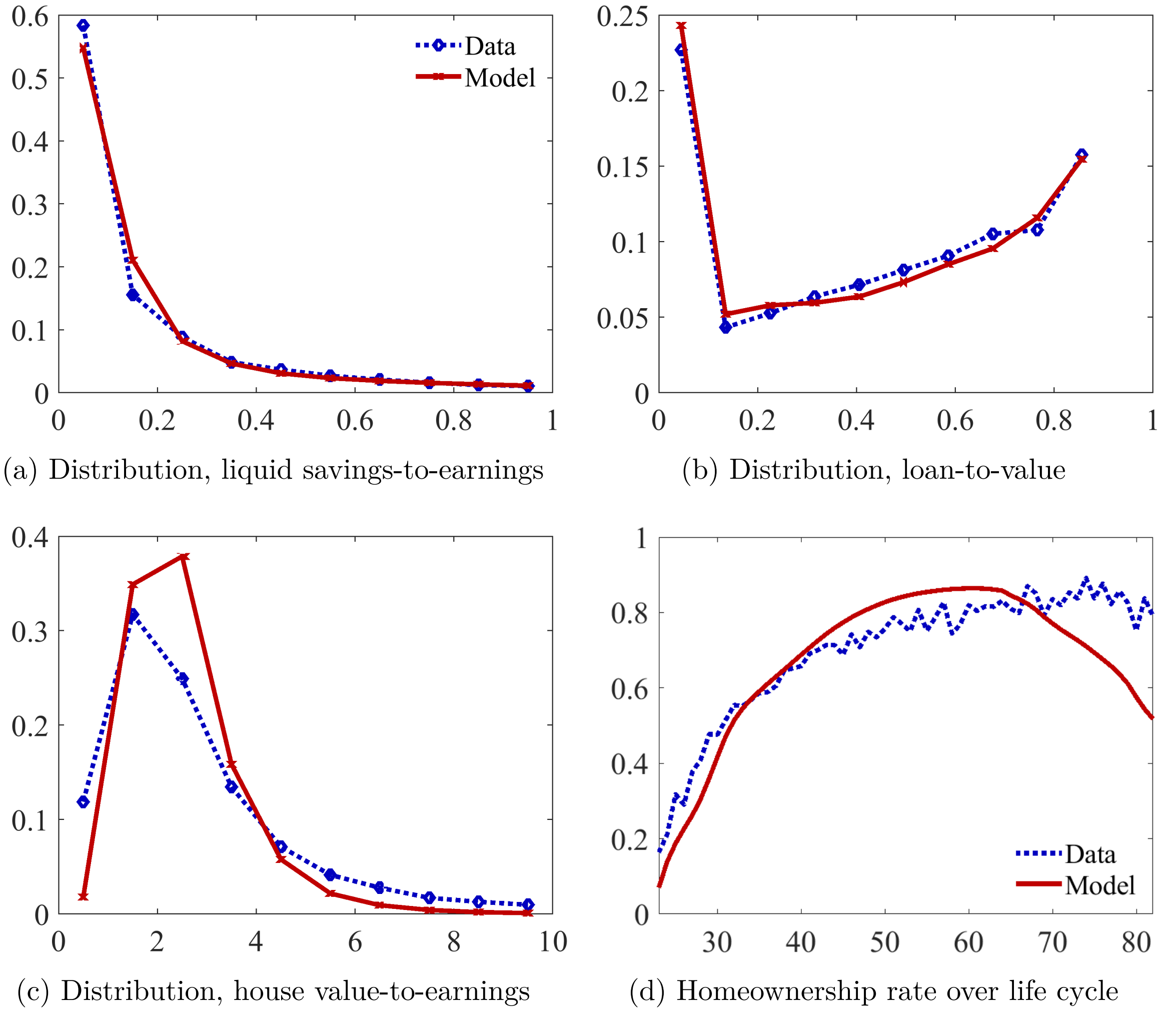


Figure 3: Comparison of data versus model

Note: The data is from the SCF, survey years 1989-2019. The model refers to the baseline economy. In Figure 3a and Figure 3c, only working-age households are included, and Figure 3b only displays homeowners.

4.3 Data versus model: distributions

The effect on MPCs of changes to the down-payment requirement depends on how constrained households are to begin with. It is therefore important to compare cross-sectional features of our model against the data for variables that can indicate if households are constrained. Figure 3 shows the distributions of liquid savings-to-earnings, LTVs, and house value-to earnings for the model and for the data from the SCF.[23] These distributions are relevant as they indicate the size of households' buffers that can be used to cushion an unexpected fall in income. Overall, the model does an excellent job in terms of matching the distributions of liquid savings and debt, which are both untargeted variables in the calibration. The model also successfully matches the timing of housing purchases among households up until retirement as seen in Figure 3d, which the simple life-cycle model in Section 2 suggests is an important margin of adjustment when the down-payment constraint changes.

4.4 Empirical literature versus model: a validation exercise

To further validate the model, we compare the model's predictions to estimates in the empirical literature. The two empirical papers most closely related to our work are Aastveit et al. (2020) and Van Bekkum et al. (2019). Similar to us, they study the effects of an increase in the down-payment requirement on households' choices. However, whereas they estimate the short-run effects of introducing stricter constraints, we study the long-run effects. Moreover, their findings regard local average treatment effects of the policy, whereas we use a model to highlight and quantify how a tightening of the constraint also leads to changes in behavior among households far away from the constraint.

Their empirical strategy is to identify households who are likely to be directly affected by the change in the down-payment policy, and compare how the choices of these households change relative to a control group comprising households that are not directly affected by the policy change. More specifically, affected households need to fulfill two criteria. First, they buy a house in the year after the reform. Second, in the absence of the reform, they would have bought a house with a smaller down payment than what is allowed following the reform.[24]

Although the papers study two different countries (Norway and the Netherlands) and

[23]We define liquid savings in the SCF as the sum of cash, checking, savings, money market, and call accounts, prepaid cards, directly-held mutual funds, stocks, and bonds, less any credit card debt balance. Cash is assumed to be five percent of the balance in the variable *liq* in the SCF, similar to Kaplan and Violante (2014). We define net worth to be the sum of liquid savings and housing wealth less mortgages.

[24]The second criterion cannot be directly observed in the data. Instead, the authors use the data from previous periods to predict what down payment households would have chosen in the absence of the reform.

reforms of different magnitude, their findings are qualitatively similar in many regards. A key finding in both papers is that the affected households have less liquid wealth than under the counterfactual. This means that part of the larger down payment is financed by reducing holdings of liquid assets, which in turn should have implications for households' consumption responses to income shocks.

To investigate whether our model also predicts that affected homeowners hold less liquid assets, we solve for the transition path from our baseline calibration with a 10 percent down-payment requirement to an alternative steady state where the required down payment is 15 percent. When studying the short-run effects, house-price changes are likely to be important. Along the transition path, we therefore keep the supply of housing fixed and house prices in each period adjust to clear the housing market. We identify affected homeowners as households who continue to buy a home, but who would have chosen a smaller down payment in the absence of the stricter requirement. We then compare their choices over the transition path to their behavior in the initial steady-state equilibrium.

Figure 4 plots the mean liquid asset holdings for the affected households. Relative to their liquid asset holdings in the absence of the reform, i.e. the initial steady state, the affected households hold considerably less liquid savings in the year after the reform is implemented. However, the effect is fairly short lived and after a few years the mean liquid wealth is the same in the transition as in the counterfactual steady-state analysis. This relatively fast convergence is similar to what Van Bekkum et al. (2019) find for the Netherlands.

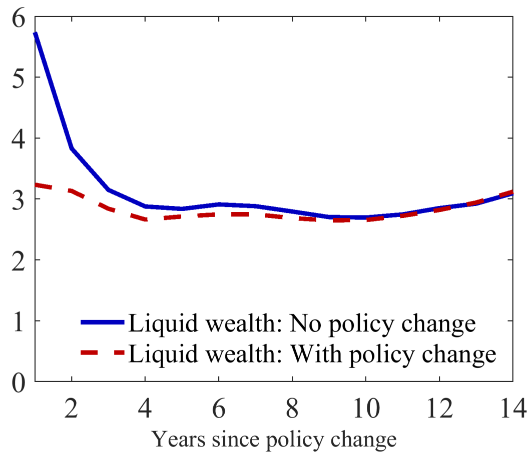


Figure 4: Mean bond holdings for affected house buyers

Note: The mean holdings of liquid bonds in each period after a house purchase among affected households, measured in 1000's of 2019 dollars. The affected households are defined as those who would have bought a house in the initial steady state with a loan-to-value ratio above the stricter loan-to-value requirement, but instead buy with less leverage when the policy is introduced.

The model also performs well in matching other results in Aastveit et al. (2020) and Van Bekkum et al. (2019). For example, the overall mortgage issuance falls and a substantial share of homeowners delay their house purchase. Thus, the extensive margin of house purchases is relevant also in the short run. Overall, our results of the short-run implications of changing the down-payment requirement are qualitatively in line with results in the empirical literature.

5 Quantitative results

Equipped with our model, we turn to the quantitative analysis. We start by examining how permanent changes to the down-payment requirement affect savings, portfolio, and consumption choices, and in turn, what this implies for MPCs. We then proceed by studying the implications of changes to the down-payment constraint for fiscal and monetary policy.

The marginal propensity to consume for household i of age j is defined as follows.

$$MPC_{ij} \equiv \frac{c_{ij}(z, x + \Delta_x, h, m) - c_{ij}(z, x, h, m)}{\Delta_x}, \tag{15}$$

where $c_{ij}(z, x, h, m)$ is consumption for household i of age j if there is no shock, and $c_{ij}(z, x + \Delta_x, h, m)$ is consumption when there is an unexpected shock of size Δ_x to cash-on-hand. Intuitively, the MPC is the fraction of the shock Δ_x that is spent on non-housing consumption. In the baseline analysis, we consider a shock of -1 000 dollars[25]. This is a significant shock, but still small enough to ensure that all households have positive cash-on-hand. In Appendix E.3, we show that our main results are robust to other shock sizes and the sign of the shock. To focus on the direct effects on demand, we abstract from possible propagation mechanisms through changes in, e.g., prices caused by the shocks. In Appendix E.2, we allow for house prices to respond to changes in the down-payment requirement, and the results still carry through since we find that the equilibrium price changes are relatively small.

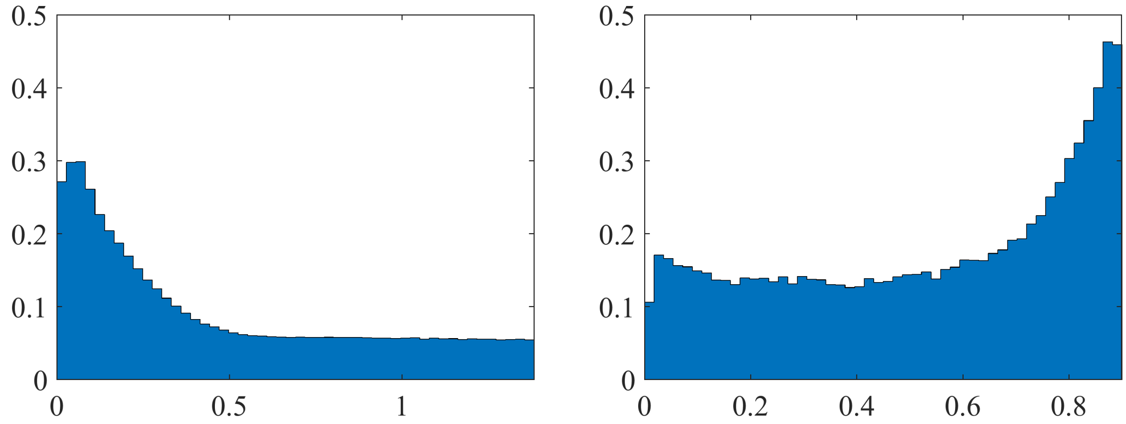
5.1 How does a stricter down-payment requirement affect consumption responses to income shocks?

Before we study the impact of changing the down-payment requirement, it is useful to understand how households' MPCs vary with liquid savings and leverage. Figure 5a displays the mean MPC across different ratios of liquid savings-to-earnings. As expected,

[25] Hereafter, dollar refers to 2019 dollar value.

the average MPC is low for households who have considerable liquid savings and high for households with little or no liquid assets. However, the mean MPC for households with low levels of liquid savings is more muted than it would have been in a one-asset model. In our model, some households optimally choose to hold little liquid savings because they can cushion shocks in other ways. For example, some households expect to pay off more on their mortgage than what is stipulated by their amortization plan and can thus adjust by paying off less in response to an income shock. Homeowners also have the option to refinance or even sell their house. Hence, liquid savings-to-earnings is not a sufficient statistic for households' MPCs in our model.

Figure 5b displays the mean MPC across households with different LTV ratios. The MPC is clearly increasing in LTVs. Households with low levels of debt have MPCs of around 0.15. In contrast, households with an LTV close to the limit of 90 percent have a mean MPC of almost 0.5. A household with only 10 percent equity in the house tends to also have low levels of liquid savings, and is therefore relatively constrained. Moreover, these households do not have the option to refinance their mortgage, as they are close to the maximum LTV limit.



(a) Liquid savings-to-earnings

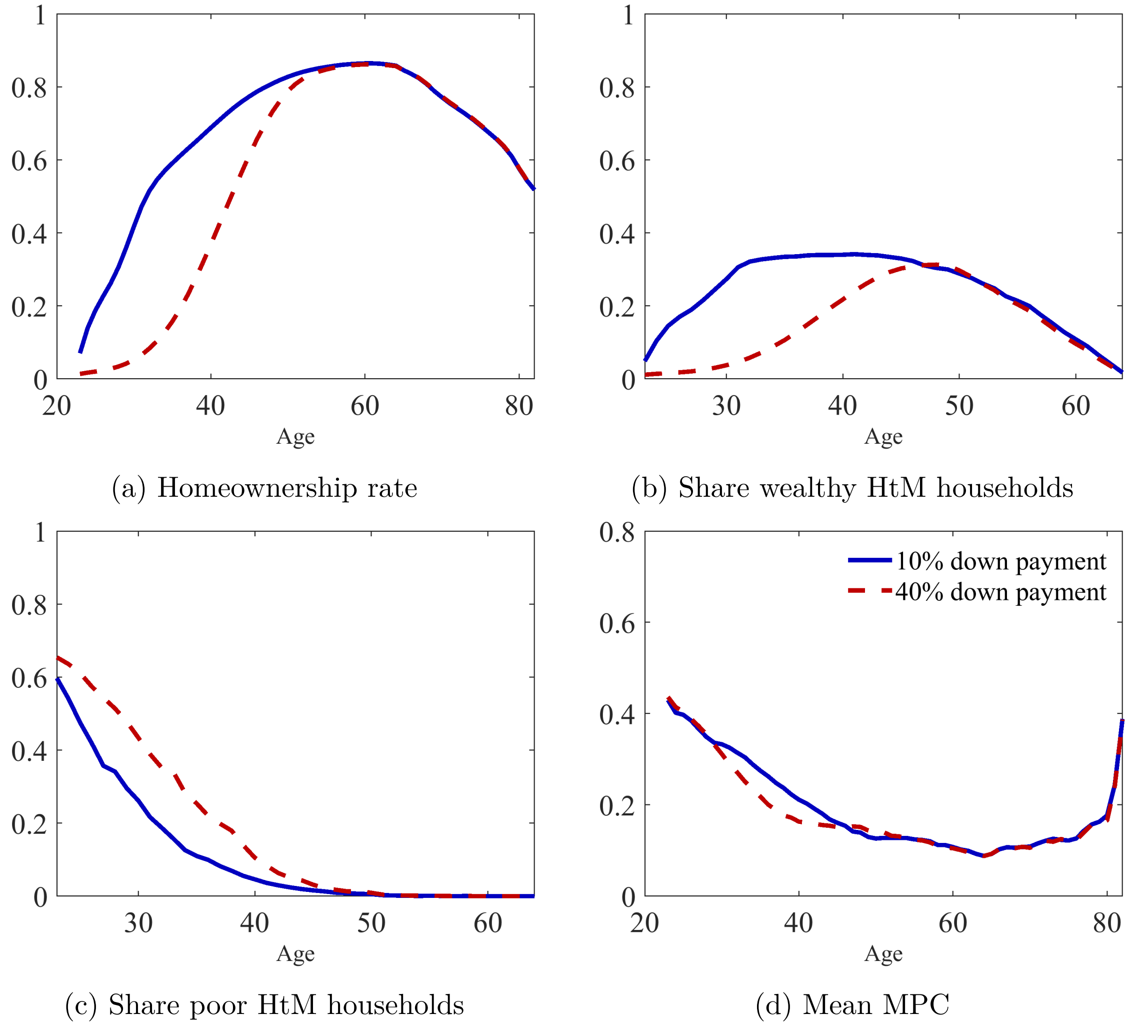
(b) Loan-to-value

Figure 5: Mean MPC by liquid savings-to-earnings and LTV in the benchmark economy
Note: Liquid savings-to-earnings and loan-to-value are divided into 50 equally sized bins. Within each bin, the mean MPC is computed. To clearly depict the part of the distribution where households are somewhat constrained, the maximum threshold is set at the 95th percentile for liquid savings-to-earnings.

Based on the strong positive correlation between MPC and LTV in Figure 5b, one may be tempted to conclude that an effective way to reduce the average MPC in the economy is to increase the down-payment requirement. However, there are several reasons that could cause this conclusion to be wrong. As discussed in Section 2, changes to the down-payment constraint impact different households differently. For instance, while a stricter constraint may induce some previously constrained homeowners to instead become unconstrained renters, other previously unconstrained homeowners may become constrained. Moreover, some households who rent their home may adjust their savings choices in response to stricter lending standards, which in turn affects their MPC. To quantify all of these effects, we proceed with our main analysis.

We begin by comparing our baseline setting with a down-payment constraint of 10 percent to an economy where the requirement is 40 percent. This is a substantial increase in the constraint and it is mainly chosen to clearly illustrate the mechanisms of the model. In Figure 6, we see that young households postpone buying a house when the down-payment constraint is stricter. The same mechanism as in the simple life-cycle model in Section 2 applies. When the down-payment requirement is increased, saving up for a house becomes more costly in utility terms for young households. As a result, households wait longer before they start to save, are now older when they buy their first home, and the share of wealthy HtM households therefore decreases among the relatively young.[26] In contrast, the share of HtM renters increases as the incentive to save is weaker for the young households. In addition to the extensive-margin response of delaying house purchases, we also find that households choose houses of smaller size/lower quality in response to the stricter requirement, as seen in Figure 12 in Appendix E.1. Finally, we note in Figure 6d that the changes in the shares of wealthy and poor HtM households translate into changes in the mean MPC over the life cycle. The stricter down-payment constraint causes the MPC to increase among the youngest households and to decrease among the older households.

[26]As illustrated in Figure 5, there is no single household variable, such as liquid savings, that can summarize how constrained a household is. We therefore classify households as HtM according to their MPCs. In this section, we assume that a household is constrained if it has an MPC above 0.3. In Appendix E.4, we show that our results are similar for other threshold levels.



(a) Homeownership rate (b) Share wealthy HtM households

(c) Share poor HtM households (d) Mean MPC

Figure 6: The effects of an increased down-payment requirement over the life cycle

Figure 7 presents how the mean MPC changes for a range of down-payment requirements. Similarly to the simple model, the mean MPC is U-shaped in the down-payment constraint. The minimum is achieved at a down-payment requirement of approximately 40 percent. At this level, the mean MPC is reduced by roughly 5 percent compared to its current level, when the down-payment requirement is 10 percent. Hence, the down-payment constraint has a relatively small impact on mean MPC, although households substantially alter their portfolio and savings choices. Since the shares of poor and wealthy HtM households move in opposite directions when changing the down-payment requirement, the effect on average MPC is relatively modest while the distributional effects of who is constrained are large. This means that the aggregate implications of a shock or macroeconomic policy may be affected by the down-payment constraint, depending on the distribution of household exposure. These distributional considerations, and their implications for policy, we turn to next.

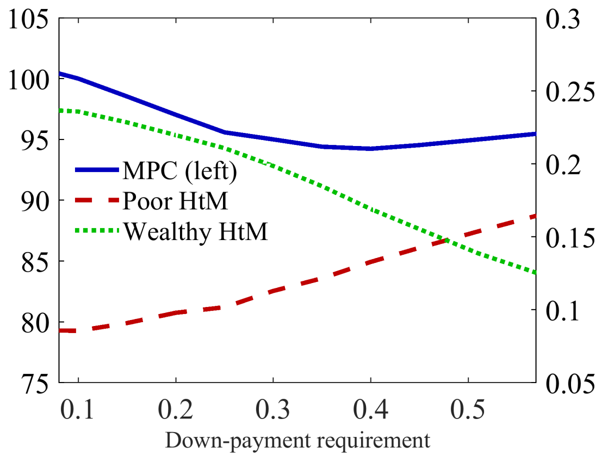


Figure 7: Mean MPC (percent of baseline) and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements

5.2 Effects on MPCs across the income distributions

To better understand how the distribution of MPCs shift with the change in policy, we divide households into three groups and investigate the average MPC within each group. The results are illustrated in Figure 8.[27] The low-income group has an average MPC that is relatively high and stable across the different levels of the down-payment constraint. These households are mostly renters who save little or nothing for the down payment. As their liquid savings are limited, they tend to respond strongly to cash transfers regardless of the level of the constraint, and a stricter requirement only has a modest effect on their mean MPC.

The middle-income group consists of both renters and homeowners at the current level of the constraint. Their mean MPC, on the other hand, is U-shaped in the down-payment constraint. For low levels of the constraint, many households in this group are wealthy HtM households. When the constraint becomes stricter, the mean MPC falls since the fraction of wealthy HtM households is reduced. For higher levels of the down-payment requirements, many of the middle-income households stop saving for housing purposes and become renters with little liquid savings, which causes their mean MPC to increase.

The high-income group mostly consists of homeowners, and their mean MPC decreases with the down-payment requirement. Also in this group, a substantial fraction of the households are wealthy HtM households at the current level of the requirement. As the constraint increases, many of them postpone their house purchase. However, most high-income households continue to save when they rent, either for life-cycle or housing

[27]Low income corresponds to households at the bottom 20 percent of the earnings distribution. High income household are the top 30 percent of the income distribution. The remaining households constitute the middle-income group.

purposes. Hence, while many of the middle-income households become renters with high MPCs, high-income households tend to become renters with low MPCs. As a result, the mean MPC is falling for this group.

These results are important when considering the design of various cash-transfer schemes. If such policies are at least partly motivated by a desire to increase aggregate consumption, targeting low-income households become increasingly important if the down-payment requirement is stricter. A similar point can be made about other changes to income, such as those caused by aggregate shocks or business-cycle fluctuations. For instance, in a standard neoclassical model with competitive markets, a shock to TFP would translate into the same proportional change in earnings for all households.[28] This implies a larger absolute change for high earners, whose MPCs are lower under tighter down-payment constraints, implying a smaller response in aggregate demand. A shock that is instead skewed towards low-earning households would have the opposite implications for the aggregate consumption response.

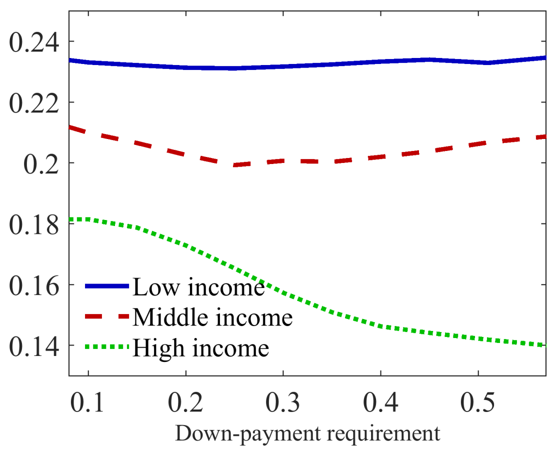


Figure 8: Mean MPC for different income groups, across various down-payment requirements

5.3 The welfare costs of stricter down-payment requirements

So far, we have seen that tightening the down-payment requirement has substantial effects on households' portfolio choices and MPCs, but that the effect on the average MPC is modest. The fact that agents see a need to re-optimize their choices in response to a stricter constraint suggests that the welfare effects are non-negligible. Although our goal is not to make a full normative analysis of the total welfare effects of different down-payment constraints, it is informative to evaluate how costly a stricter requirement is from the

[28] We look at this scenario in Appendix E.9.

perspective of the households.[29]

To quantify the welfare costs of households, we calculate the compensating variation (CV) associated with increasing the down-payment requirement. The CV is defined as the lump-sum tax that has to be imposed on each household at age $j = 1$, in a setting with a stricter down-payment constraint, to make them as well off as they are in the baseline economy, with a down-payment requirement of 10 percent. Formally, the CV for each household i is defined by γ_i such that

$$V_1^{new}(z_i, (1 + \gamma_i))x_i, h_i, m_i) = V_1^{base}(z_i, x_i, h_i, m_i), \tag{16}$$

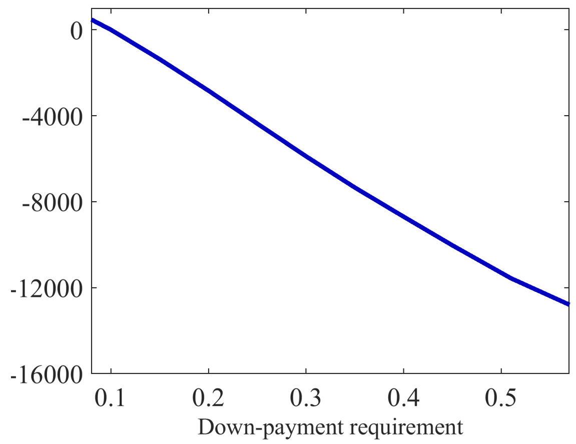
where V^{base} is the value function for the baseline calibration with $\theta = 0.1$ and V^{new} is the value function for the stationary equilibrium with an alternative down payment.

As illustrated in Figure 9a, the welfare costs of a stricter down-payment constraint are substantial. For example, the average household would require a transfer of almost 3,000 dollars to make them equally well off in a setting with a 20 percent down-payment requirement as in the economy with a 10 percent constraint. To put this into perspective, this transfer is equivalent to 5.4 percent of the mean income of 23-year-olds.

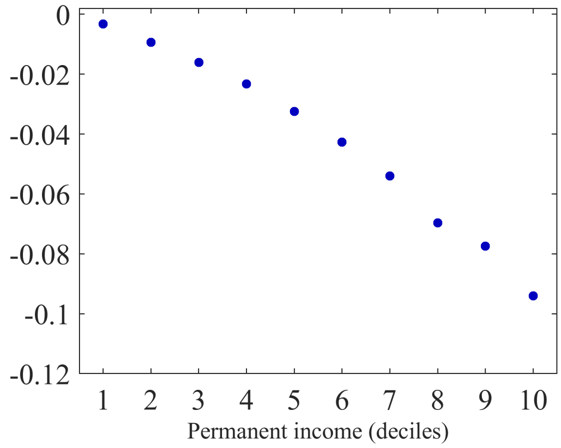
Since we measure the total expected welfare effects over life, the only heterogeneity among households is driven by initial differences in income and net worth, which together make up a household's cash-on-hand x_i at age 23. Figure 9b illustrates how the welfare effects very across income, when comparing the baseline economy to a setting with a 20 percent down-payment constraint. For ease of comparison, we express the CV as a fraction of households' cash-on-hand rather than absolute amounts. Quite strikingly, the households who are worst affected by the policy are those with high levels of income. For the decile with the highest income, the welfare loss is equivalent to approximately 10 percent of cash-on-hand. In contrast, the households with the lowest income barely lose at all.

There are three main reasons why high-income households are the worst off from a stricter down-payment constraint. First, only those who buy a house at some point in their life are directly affected by the policy. Households who start life with low earnings are more likely to have low earnings later in life, which in turn makes them less likely to ever become a homeowner. Second, and relatedly, households with high earnings tend to buy a house relatively early in life. An increase in the down-payment requirement therefore affects them at a point in their life where earnings are relatively low and quickly increasing. As a result, the stricter constraint makes them save more to buy a home

[29] Our model is not set up to make a full-fledged welfare analysis, as there is no benefit of a stricter down-payment constraint. Nonetheless, in the current environment we can still evaluate the welfare costs of the households.



(a) Average CV for different down-payment requirements



(b) Average CV, expressed as share of cash-on-hand, across income deciles

Figure 9: Welfare consequences of altering the required down-payment

when this is relatively costly in utility terms, as compared to low-income households who tend to purchase a house closer to the peak of the income profile. As highlighted in Section 2, high-earnings households adjust their savings behavior more in response to a stricter policy. They postpone their house purchase more than low-earning households do, and they respond more in terms of choosing smaller houses. Lastly, discounting affects how different households are differently affected by a stricter constraint. Since a larger down-payment requirement affects high earners earlier in life, their welfare losses are discounted for fewer periods, than the losses of low-earners.

5.4 The effectiveness of monetary policy and down-payment constraints

Since households' asset and debt choices depend on the down-payment constraint, households' exposure to monetary policy is also influenced by changes to the constraint. To examine how monetary policy interacts with the down-payment requirement, we consider a 1 percentage point unexpected shock to the interest rate on liquid bonds and mortgages, under various down-payment regimes. We restrict our attention to direct cash-flow effects of monetary policy, which have been shown to play a key role in the transmission of monetary policy (Calza et al., 2013; Cloyne et al., 2019; Di Maggio et al., 2017; Flodén et al., 2020; Guren et al., 2021; Holm et al., 2021; Kinnerud, 2022; Verner and Gyöngyösi, 2020). The solid line in Figure 10a displays the mean consumption response to a one-time increase in the interest rates of 1 percentage point, for different levels of the down-payment requirement.[30] We see that the direct cash-flow effects of monetary policy are highly dependent on the down-payment constraint. At the current level of the requirement, consumption contracts by approximately 0.18 percent in response to the interest-rate increase. However, with a down-payment constraint of 30 percent the consumption response is approximately halved. At very strict levels of the constraint, the consumption response can even be positive.

The direct consumption response of the interest-rate shock follows from the effect the change in the interest rate has on different households' cash flows and how this effect correlates with MPCs. The dotted line in Figure 10a presents the consumption response due to the increase in mortgage interest payments, whereas the dashed line shows the effect due to the higher return on liquid savings. First, we note that the consumption response that stems from the higher return on bonds is relatively unimportant and unrelated to changes in the down-payment constraint. Although the interest-rate shock significantly impacts households' cash flows through their bond holdings, households with large liquid savings also tend to have small MPCs.

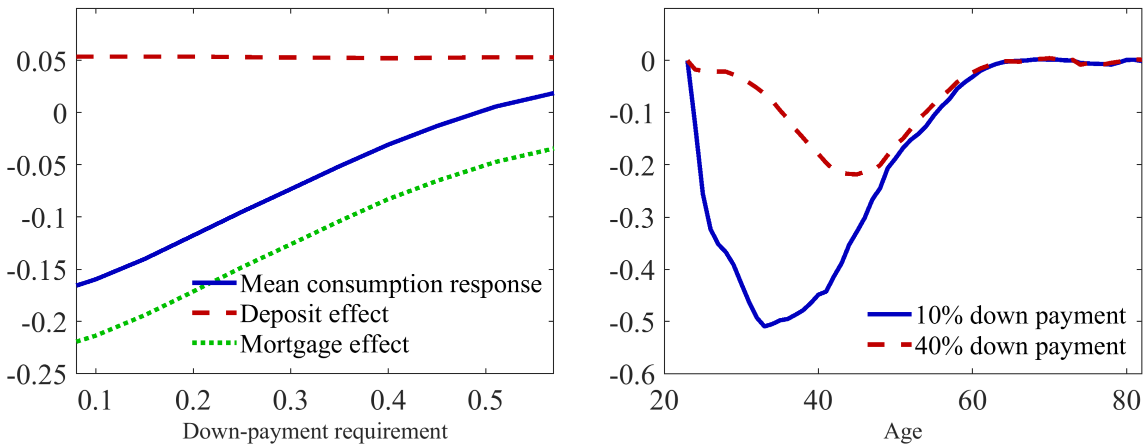
Second, the importance of the mortgage cash-flow channel can be substantial and varies greatly with the down-payment constraint. When the required down payment is small, many households have large mortgage balances, implying large changes in cash flows due to the interest rate shock. In addition, since the indebted households also tend to have low levels of liquid savings, their consumption response is strong. For stricter down-payment constraints, the cash-flow channel through the mortgage market is significantly reduced. Figure 10b shows that this is mostly due to a more muted response among young households, as they postpone buying a house and take up smaller mortgages on average.

We conclude that although a stricter down-payment requirement can make the economy more stable, in the sense that the mean MPC declines, it also makes monetary policy less potent. The reduced effectiveness is largely explained by a dampened mortgage cash-flow channel.

6 Concluding remarks

Since the Great Recession, policymakers in many countries have implemented stricter mortgage lending standards. In particular, down-payment requirements are more commonly used and their limits are more stringent, meaning that households are required to finance a larger share of house purchases with their own equity. In this paper, we investigate how households' consumption, savings, and portfolio choices are affected by

[30] For this exercise we are assuming that mortgages have adjustable interest rate.



(a) Consumption response (b) Consumption response, mortgage effect

Figure 10: Mean consumption responses to a transitory one percentage point rise in the interest rate

a stricter down-payment constraint, and what the implications are for macroeconomic policy.

We show that, under general assumptions, requiring households to save up more to buy a house in fact lowers their willingness to save early in life. This drop in savings among young households makes them more credit constrained, and the number of poor households with high MPCs increases. On the other hand, a stricter down-payment requirement also leads to fewer homeowners, and the age of first-time buyers increases. As a result, the share of wealthy homeowners with high MPCs decreases. Hence, despite substantial distributional effects on households' consumption, savings, and portfolio choices, which are associated with large welfare losses, the mean MPC is relatively insensitive to changes in the down-payment constraint. The distributional effects do however influence the effectiveness and transmission mechanism of macroeconomic policy. Concretely, we find that a stricter down-payment constraint significantly reduces the effectiveness of monetary policy, and fiscal transfers are relatively more effective if targeting young households with low income.

There are a number of extensions to the analysis that provide promising avenues for future research. First, in our quantitative analysis we find that a stricter down-payment constraint has a fairly small effect on mean MPC, while the welfare costs of such a policy are large. A normative analysis of borrower-based macroprudential policy, when also modeling the lender-side of the market, could provide valuable insights for policy makers. Second, it would be interesting to see whether our results are generalizable to other types of shocks, such as changes to house prices. Third, it may also be worthwhile to investigate other forms of mortgage lending standards, such as the payment-to-income requirement.

Since this type of constraint restricts mortgage lending based on household's income, it may bind for a different set of households.

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Appendices

A Conceptual frameworks where housing is not explicitly modeled

This section studies a model where the down-payment constraint is simply a savings threshold for receiving a utility bonus, which resembles the additional utility derived from owning a house. We first study a two-period version of this model and highlight how changes in the down-payment requirement and a traditional borrowing constraint have fundamentally different implications for MPCs. We then extend this framework to a life-cycle setting to capture how changes in the down-payment constraint affect savings dynamics. The life-cycle model is isomorphic to the model presented in Section 2.

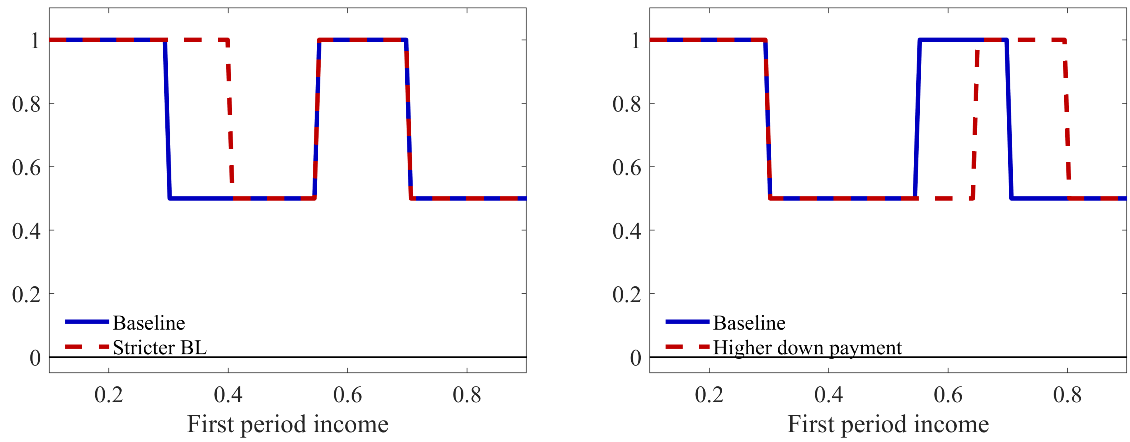
A.1 A two-period model

Let us first study the simplest possible framework that captures the main difference between a traditional borrowing constraint and a down-payment requirement. Consider a standard two-period household problem. In the first period, a household has income y_1 and chooses how much to consume c_1 and save in a risk-free bond b. In the second period, the household spends income y_2 and its savings $(1 + r)b$ on consumption c_2. We add two constraints to this problem. The first is a classic borrowing limit, i.e., $b \geq \underline{b}$. The second is a savings threshold $b^* > \underline{b}$, where households who save more than this amount receive a utility bonus Ψ. We regard the threshold b^* as a down-payment requirement, because it resembles the savings that are required in order to purchase a house. A household that chooses $b \geq b^*$ is therefore thought of as a homeowner, whereas a household that saves less will be referred to as a renter. We assume that households do not discount the future, the interest rate on savings in risk-free bonds is zero, and households have log preferences over consumption.

All households in the model are endowed with a total life-time income of one, but they differ in terms of when they receive their income. This last assumption means that we can think of first-period income y_1 as determining the slope of a household's income profile. Households with low initial income want to borrow, whereas households with high initial income want to save. The household problem is characterized by

$$
\begin{aligned}
\max_{c_1,c_2,b} U(c_1) + U(c_2) + \mathbb{I}\Psi \ s.t.& \\
c_1 &= y_1 - b \\
c_2 &= y_2 + b \\
y_1 + y_2 &= 1 \\
b &\geq \underline{\mathrm{b}} \\
\mathbb{I} &= \begin{cases} 1 \text{ if } b \geq b^* \\ 0 \text{ else.} \end{cases}
\end{aligned}
$$

The solid line in Figure 11 shows how the MPC in the first period varies across different levels of first-period income y_1 in our baseline scenario. Four types of households emerge. First, we have the poor renters. These are households with very low first-period income, who ideally would like to borrow more than $\underline{\mathrm{b}}$ to smooth consumption. Since these households would like to increase consumption in the first period, any marginal increase in income is consumed. Hence, they have an MPC of 1 and represent the so called poor hand-to-mouth (HtM) households. For higher levels of income, we have the unconstrained renters. These households are able to smooth consumption perfectly, since there is no constraint that is binding at the margin. They save more than the borrowing limit, but are not willing to save sufficiently to finance the down payment. Any marginal increase in income in the first period is therefore split equally between consumption and savings, implying an MPC of 0.5. The third type of household is the constrained homeowners, who choose to save exactly what is required for the down payment. To pay for the down payment and thus receive the utility bonus of owning, these households hold back on consumption in the first period. Hence, their consumption is lower than needed to smooth consumption over the two periods and any marginal increase in income in the first period is consumed. Thus, despite having positive wealth, these households have an MPC of 1, and represent the so called wealthy HtM households. Finally, the homeowners with first-period income such that their savings for consumption-smoothing purposes exceed b^*, are unconstrained and have an MPC of 0.5.



(a) Changing the borrowing constraint (b) Changing the down-payment constraint

Figure 11: MPC in a two-period model

As this relatively simple model is able to generate both poor and wealthy HtM households, as well as unconstrained households with modest MPCs, we can fruitfully examine how changes in the two constraints affect a variety of household types. The dashed line in Figure 11a depicts households' MPC when the borrowing limit is tightened. We see that a stricter borrowing requirement weakly increases MPCs. Intuitively, households who previously saved more than the old borrowing limit, but less than the new one, are now forced to save more. These formerly unconstrained renters now become poor HtM households. Since the tighter borrowing constraint does not change incentives to save per se, all other households are unaffected and their MPCs are unchanged.

The dashed line in Figure 11b illustrates households' MPC when we instead increase the down-payment requirement. In contrast to the case of a stricter borrowing constraint, the mean MPC can increase *or* decrease in response to a stricter down-payment requirement. On the one hand, some households no longer find it worthwhile to save the amount required to obtain the utility bonus, as it means lowering first-period consumption even further. Instead, they choose to become renters to better smooth consumption across the two periods. This reduces their MPC. On the other hand, some previously unconstrained homeowners are now limited by the tougher requirement. These households previously saved more than the old down-payment constraint, but in order to comply with the new requirement they have to increase their savings. This increases their MPC. Overall, the stricter down-payment requirement causes a shift in the composition of wealthy HtM households towards households with higher income. Consequently, the effect on the average MPC depends on the income distribution in the economy.

A.2 A life-cycle model

While the two-period model establishes that the down-payment constraint differs from a traditional borrowing limit in important ways, interesting life-cycle aspects are missed. In particular, changes to the down-payment constraint affects the timing of housing purchases. We argue in Section 2 that this mechanism is key to include, as the decision of when to buy a house is crucial for households' savings dynamics and MPCs. To further back up this claim, this section shows that the model in Section 2 is isomorphic to a model where housing is not explicitly included, and the down-payment requirement can instead be thought of as a savings threshold for obtaining a utility bonus. This model is then reformulated in continuous time, which allows us to show in closed form that the result in Section 2 is very general.

Consider the model from Section 2:

$$
\begin{aligned}
V_j(x) &= \max_{c,b',h'} U(c,h') + V_{j+1}(x') \; s.t. \\
h' &\in \{0, \bar{h}\} \\
c &= x - b' - h' && \text{Budget constraint} \\
x' &= y' + b' + h' && \text{LoM cash-on-hand} \\
b' &\geq 0 && \text{if } h' = 0 \\
-b' &\leq (1-\theta)h' && \text{if } h' = 1 \\
U(c,h') &= \log(c) + h'\Psi,
\end{aligned}
$$

Next, define total savings $a' \equiv b' + h'$. Then the above problem can be written as

$$
\begin{aligned}
V_j(x) &= \max_{c,a',h'} \log(c) + h'\Psi + V_{j+1}(x') \; s.t. \\
h' &\in \{0, \bar{h}\} \\
c &= x - a' \\
x' &= y' + a' \\
a' &\geq 0 \text{ if } h' = 0 \\
a' &\geq \theta\bar{h} \text{ if } h' = 1
\end{aligned}
$$

The binary choice of h' gives the household two possibilities: either it chooses $h' = 0$ ard receives no utility bonus, or it chooses $h' = \bar{h}$ which gives the bonus but forces the household to save up at least $a' = \theta\bar{h}$. The problem can therefore be formulated as

$$V_j(x) = \max_{c,a'} \log(c) \; + \mathbb{I}\bar{h}\Psi + V_{j+1}(x') \; s.t.$$
$$c = x - a'$$
$$x' = y' + a'$$
$$a' \geq 0$$
$$\mathbb{I} = \begin{cases} 1 \text{ if } a' \geq \theta\bar{h} \\ 0 \text{ else.} \end{cases}$$

The problem has now been reduced to one without housing, where the only deviation from the textbook problem is that once the asset holdings exceed some prespecified amount $\theta\bar{h}$, the household receives some extra utility.

A.3 A life-cycle model in continuous time

A.3.1 The model and the role of timing

Consider the formulation in A.2. For simplicity, and without loss of generality, we can rescale θ and Ψ such that $\bar{h} = 1$. Furthermore, return to the practice of denoting the liquid asset by b. The model can then be stated in continuous time as

$$\max_{\{c_t, b_t\}} \int_0^T (u(c_t) + \mathbb{I}\Psi) \, dt \; s.t.$$
$$c_t + \dot{b}_t = y_t$$
$$b_t \geq 0$$
$$\mathbb{I} = \begin{cases} 1 \text{ if } b_t \geq \bar{b} \\ 0 \text{ otherwise,} \end{cases}$$

where t is used to denote time. For the remaineder of this section, we are going to assume that earnings y_t is an increasing function of time.

The household problem has three potential solutions for each point in time. At each non-convexity, the household consumes its income $c_t = y_t$ and saves according to the constraint implying $\dot{b}_t = 0$. The third possibility is an interior solution where $0 < b_t < \bar{b}$ and the household perfectly smooths consumption $\dot{c}_t = 0$ according to its Euler equation. After the down payment is reached, there is no incentive for the household to accumulate any further wealth, since income is increasing with time. Hence, this rules out the possibility of an interior solution above $\bar{b}$.

Label the point at which households start to save by $\hat{t}$ and the period at which the down payment is reached by $\bar{t}$. Since income is strictly higher than $y_{\hat{t}}$ in all time periods $t \in]\hat{t}, \bar{t}[$ and consumption is constant during the period that households save, total savings increase in all periods from $\hat{t}$ until the down-payment requirement is reached. Consumption will be equal to the income at the point in time when the households start to save, that is, $c_t = y_{\hat{t}} \; \forall \; t \in]\hat{t}, \bar{t}[$. Therefore, the accumulated savings at time $\tilde{t}$ within this interval is

$$b_{\tilde{t}} = \int_{\hat{t}}^{\tilde{t}} (y_t - y_{\hat{t}}) dt.$$

The time of purchase will therefore be the timing $\bar{t}$ that satisfies

$$\bar{b} = \int_{\hat{t}}^{\bar{t}} (y_t - y_{\hat{t}}) dt. \tag{17}$$

Since $y_{\hat{t}}$ depends on $\hat{t}$, this implies that the purchase timing is also a function of the timing of when to start saving, i.e., $\bar{t} = \bar{t}(\hat{t})$. We can put further structure on this relationship by considering how wealth changes when $\hat{t}$ is increased. By the Leibniz integral rule, this is

$$\frac{d\bar{b}}{d\hat{t}} = [y_{\bar{t}} - y_{\hat{t}}] \frac{d\bar{t}}{d\hat{t}} - (\bar{t} - \hat{t}) \dot{y}_{\hat{t}},$$

where $\dot{y}_{\hat{t}} \equiv \frac{dy_{\hat{t}}}{d\hat{t}}$. For a fixed down payment, the change is zero. This implies

$$\frac{d\bar{t}}{d\hat{t}} = \frac{\dot{y}_{\hat{t}} \left(\bar{t} - \hat{t} \right)}{y_{\bar{t}} - y_{\hat{t}}}. \tag{18}$$

As long as income is upward sloping, we have $\frac{d\bar{t}}{d\hat{t}} > 0$. Thus, whenever a household decides to start saving at a later point in time it also delays its housing purchase.

A.3.2 What is the optimal timing?

The value function is given by

$$V(\hat{t}) = \int_0^{\hat{t}} u(y_t) dt + \int_{\hat{t}}^{\bar{t}} u(y_{\hat{t}}) dt + \int_{\bar{t}}^{T} u(y_t) dt + (T - \bar{t}) \Psi. \tag{19}$$

For intuition, it is useful to contrast this to the value of not saving up for the down payment at all. In that case, consumption equals income in all periods. The difference in value between saving up for the house, starting at some time point $\hat{t}$, and the option of not saving at all is

$$V(\hat{t}) - \int_0^T u(y_t)dt = (T - \bar{t})\Psi - \int_{\hat{t}}^{\bar{t}} (u(y_t) - u(y_{\hat{t}}))dt. \tag{20}$$

The above equation illustrates the trade-off when saving for the down payment. On the one hand, by saving the household eventually obtains the down payment at some point $\bar{t}$, after which it enjoys the extra utility Ψ for the remainder of life. This is the first term of the expression. On the other hand, there is also a cost associated with this, as during the period that the household saves it has to forgo some consumption. This cost is the second term in the above expression.

The problem of the household is to choose the optimal time point $\hat{t}$, where the difference between benefit and cost is maximized. This is pinned down by the first-order condition of equation (20). This is

$$V'(\hat{t}) = -\psi \frac{d\bar{t}}{d\hat{t}} - \left([u(y_{\bar{t}}) - u(y_{\hat{t}})] \frac{d\bar{t}}{d\hat{t}} - [u(y_{\hat{t}}) - u(y_{\hat{t}})] \frac{d\hat{t}}{d\hat{t}} - \int_{\hat{t}}^{\bar{t}} u'(y_{\hat{t}}) \dot{y}_{\hat{t}} dt \right) = 0,$$

which simplifies to

$$u'(y_{\hat{t}})\dot{y}_{\hat{t}} \left(\bar{t} - \hat{t} \right) - [u(y_{\bar{t}}) - u(y_{\hat{t}})] \frac{d\bar{t}}{d\hat{t}} - \psi \frac{d\bar{t}}{d\hat{t}} = 0. \tag{21}$$

The three terms in (21) have an intuitive interpretation. The first term captures the benefit of postponing savings to a later point in time. When a household chooses to postpone its savings, its income (and consumption) is higher at the time it starts to save. Thus, in every period $\hat{t}$ to $\bar{t}$, the household receives an extra utility $u'(y_{\hat{t}})\dot{y}_{\hat{t}}$, i.e., the marginal utility of consumption times the wage growth at time $\hat{t}$. The remaining two terms capture the negative effects on welfare. The second term captures that a delay in housing purchase, due to a postponement of when to save, is costly as it requires the household to save for the down payment in periods where it previously had sufficient savings. The last term captures the utility loss from not receiving the bonus ψ due to a delay in housing purchase.

By substituting $\frac{d\bar{t}}{d\hat{t}}$ using equation (18), the expression can be written as

$$u'(y_{\hat{t}})\dot{y}_{\hat{t}} \left(\bar{t} - \hat{t} \right) = [u(y_{\bar{t}}) - u(y_{\hat{t}}) + \psi] \frac{\dot{y}_{\hat{t}} \left(\bar{t} - \hat{t} \right)}{y_{\bar{t}} - y_{\hat{t}}},$$

which simplifies to

$$u'(y_{\hat{t}}) = \frac{u(y_{\bar{t}}) - u(y_{\hat{t}}) + \psi}{y_{\bar{t}} - y_{\hat{t}}}. \tag{22}$$

Equation (22) pins down the optimal choice of timing $\hat{t}$.

A.3.3 Is the solution unique?

To see under what circumstances the solution is unique, label the the two sides of (22) as

$$\begin{aligned} f(\hat{t}) &\equiv u'(y_{\hat{t}}) \\ g(\hat{t}) &\equiv \frac{u(y_{\bar{t}}) - u(y_{\hat{t}}) + \psi}{y_{\bar{t}} - y_{\hat{t}}} \end{aligned}$$

and take the derivative with respect to $\hat{t}$. It can be shown that the derivatives are[31]

$$\begin{aligned} f'(\hat{t})' &= u''(y_{\hat{t}})\dot{y}_{\hat{t}} \\ g'(\hat{t}) &= \frac{\dot{y}_{\hat{t}}[u'(y_{\bar{t}}) - u'(y_{\hat{t}})]}{y_{\bar{t}} - y_{\hat{t}}} \frac{\dot{y}_{\bar{t}}\left(\bar{t} - \hat{t}\right)}{y_{\bar{t}} - y_{\hat{t}}}. \end{aligned}$$

Both are negative as long as the utility function is concave and wages are increasing over time. Note that $f'(\hat{t}) < g'(\hat{t})$ if

$$u''(y_{\hat{t}}) < \underbrace{\frac{u'(y_{\bar{t}}) - u'(y_{\hat{t}})}{y_{\bar{t}} - y_{\hat{t}}}}_{A} \underbrace{\frac{\dot{y}_{\bar{t}}(\bar{t} - \hat{t})}{y_{\bar{t}} - y_{\hat{t}}}}_{B}. \tag{23}$$

By concavity of the utility function, it is always the case that $u''(y_{\hat{t}}) < A < 0$. This means that a sufficient, but not necessary, condition for (23) to hold is that $B \in [0, 1]$. Note that the numerator of B is the change in income at $\bar{t}$ extrapolated from $\bar{t}$ to $\hat{t}$. The denominator is the actual income change between these two points in time. Thus, B captures the degree of convexity of the income profile. Therefore, $B < 1$ if income is a concave function of time, $B = 1$ if it is linear, and $B > 1$ in the case of convexity. This means we can conclude that (23) always hold if y_t is concave or linear. Also, it holds in the case of convex income if the convexity of the income profile is small relative to the concavity of the utility function, such that $u''(y_{\hat{t}}) < AB$.

With concave or linear wages, the relationship in (23) also implies that the solution to (22) is unique. To see this, note that both sides of equation (22) are continuous. If there are multiple solution, this means that if there is a solution such that $f'(\hat{t}) < g'(\hat{t})$

[31] Step-by-step calculations are provided in Section A.3.7.

there also has to be at least one where $f'(\hat{t}) > g'(\hat{t})$. But this is ruled out by (23) under a concave or linear income profile.

A.3.4 How does a higher down payment affect when to buy a house?

Take the derivate of equation (17) with respect to the down payment $\bar{b}$

$$\frac{d\bar{b}}{d\bar{b}} = (y_{\bar{t}} - y_{\hat{t}})\frac{d\bar{t}}{d\bar{b}} - (y_{\hat{t}} - y_{\hat{t}})\frac{d\hat{t}}{d\bar{b}} + \int_{\hat{t}}^{\bar{t}} -\dot{y}_{\hat{t}}\frac{d\hat{t}}{d\bar{b}}dt,$$

which simplifies to

$$1 = (y_{\bar{t}} - y_{\hat{t}})\frac{d\bar{t}}{d\bar{b}} - \dot{y}_{\hat{t}}(\bar{t} - \hat{t})\frac{d\hat{t}}{d\bar{b}}.$$

Solving for $\frac{d\bar{t}}{d\bar{b}}$ yields

$$\begin{aligned}\frac{d\bar{t}}{d\bar{b}} &= \frac{1}{y_{\bar{t}} - y_{\hat{t}}} + \frac{\dot{y}_{\hat{t}}(\bar{t} - \hat{t})}{y_{\bar{t}} - y_{\hat{t}}}\frac{d\hat{t}}{d\bar{b}} \\ &= \frac{1}{y_{\bar{t}} - y_{\hat{t}}} + \frac{d\bar{t}}{d\hat{t}}\frac{d\hat{t}}{d\bar{b}},\end{aligned} \tag{24}$$

where we have used the result in equation (18) in the last step. Thus, there is a direct positive effect on the timing of housing purchase which is captured by the first term and an indirect effect through the endogenous response of the timing of when to start saving.

A.3.5 How does a higher down payment affect when to start saving for a house?

What we want to do is find the sign of $\frac{d\hat{t}}{d\bar{b}}$. Our approach is to see how the two sides of equation (22) are impacted by an increase in the down-payment requirement. The derivative of the left-hand side of equation (22) with respect to the down-payment $\bar{b}$ is

$$\frac{d}{d\bar{b}}f(\hat{t}) = u''(y_{\hat{t}})\dot{y}_{\hat{t}}\frac{d\hat{t}}{d\bar{b}} = f'(\hat{t})\frac{d\hat{t}}{d\bar{b}}, \tag{25}$$

where $f'(\hat{t}) < 0$. It can be shown that the derivative of the right-hand side of equation (22) is

$$\frac{d}{d\bar{b}}g(\hat{t}) = [u'(y_{\bar{t}}) - u'(y_{\hat{t}})]\frac{\dot{y}_{\bar{t}}}{(y_{\bar{t}} - y_{\hat{t}})^2} + g'(\hat{t})\frac{d\hat{t}}{d\bar{b}}. \tag{26}$$

The first term is always negative under the assumptions of a concave utility function and increasing wages. Recall that $g'(\hat{t}) < 0$. Thus, the sign of the second term depends on the sign of $\frac{d\hat{t}}{d\bar{b}}$.

In response to an increase in the required down payment, $\hat{t}$ must change to ensure that (22) still holds. In other words, $\frac{d}{d\bar{b}} f(\hat{t}) = \frac{d}{d\bar{b}} g(\hat{t})$, meaning

$$\left[f'(\hat{t}) - g'(\hat{t})\right] \frac{d\hat{t}}{d\bar{b}} = \left[u'(y_{\bar{t}}) - u'(y_{\hat{t}})\right] \frac{\dot{y}_{\bar{t}}}{(y_{\bar{t}} - y_{\hat{t}})^2}. \tag{27}$$

We know from before that with concave utility and a non-convex wage profile, it must be that $f'(\hat{t}) < g'(\hat{t}) < 0$, implying that the expression in the brackets on the left-hand side is negative. Under the same restrictions, the right-hand side is also negative. Therefore, it must be the case that $\frac{d\hat{t}}{d\bar{b}} > 0$. In response to an increase in the down-payment requirement, the household will postpose when it starts to save up for the house. Together with equation (24), this also implies that households will optimally choose to postpone their housing purchase when faced with a stricter down-payment requirement.

A.3.6 The case of exponentially increasing earnings

Here, we show that there exist a closed-form solution for the timing of when to start saving if we assume logarithmic utility and exponential wage growth. The earnings profile is given by

$$y_t = e^{g^y t},$$

where g^y determines the growth rate of income. First, solve the integral in equation (17) and rewrite to get

$$\frac{g^y \bar{b}}{y_{\hat{t}}} = u'(y_{\hat{t}}) \left[y_{\bar{t}} - y_{\hat{t}}\right] - g^y(\hat{t} - \bar{t}).$$

Next, rewrite the equilibrium condition (22) and use it to substitute the first term on the right-hand of the equation. The equation then simplifies to

$$\frac{g^y \bar{b}}{y_{\hat{t}}} = \psi.$$

Use the functional form of the wage profile and solve for $\hat{t}$ to get

$$\hat{t} = \frac{1}{g^y} \log\left(\frac{g^y \bar{b}}{\psi}\right). \tag{28}$$

Thus, again we confirm that the timing of when to start saving depends positively on the down-payment requirement, even if the wage profile is exponential. To be more specific, the extent to which households postpone there savings is given by

$$\frac{d\hat{t}}{d\bar{b}} = \frac{1}{g^y \bar{b}}, \tag{29}$$

which is positive and decreasing with $\bar{b}$ and g^y.

A.3.7 Step-by-step calculations

Equation (23):
Recall that $g(\hat{t}) \equiv \frac{\Psi + u(y_{\bar{t}}) - u(y_{\hat{t}})}{y_{\bar{t}} - y_{\hat{t}}}$. The derivative of $g(\hat{t})$ with respect to $\hat{t}$ is given by

$$g'(\hat{t}) = \frac{u'(y_{\bar{t}})\dot{y}_{\bar{t}}\frac{d\bar{t}}{d\hat{t}} - u'(y_{\hat{t}})\dot{y}_{\hat{t}}}{y_{\bar{t}} - y_{\hat{t}}} - \frac{\Psi + u(y_{\bar{t}}) - u(y_{\hat{t}})}{(y_{\bar{t}} - y_{\hat{t}})^2} \left[\dot{y}_{\bar{t}}\frac{d\bar{t}}{d\hat{t}} - \dot{y}_{\hat{t}}\right].$$

Substituting in (22) this can be written as

$$\begin{aligned} g'(\hat{t}) &= \frac{u'(y_{\bar{t}})\dot{y}_{\bar{t}}\frac{d\bar{t}}{d\hat{t}} - u'(y_{\hat{t}})\dot{y}_{\hat{t}}}{y_{\bar{t}} - y_{\hat{t}}} - \frac{u'(y_{\hat{t}})}{y_{\bar{t}} - y_{\hat{t}}} \left[\dot{y}_{\bar{t}}\frac{d\bar{t}}{d\hat{t}} - \dot{y}_{\hat{t}}\right] \\ &= \frac{\dot{y}_{\bar{t}}[u'(y_{\bar{t}}) - u'(y_{\hat{t}})]}{y_{\bar{t}} - y_{\hat{t}}} \frac{d\bar{t}}{d\hat{t}}. \end{aligned}$$

Substituting in (18), we can write

$$g'(\hat{t}) = \frac{\dot{y}_{\hat{t}}[u'(y_{\bar{t}}) - u'(y_{\hat{t}})]}{y_{\bar{t}} - y_{\hat{t}}} \frac{\dot{y}_{\bar{t}}\left(\bar{t} - \hat{t}\right)}{y_{\bar{t}} - y_{\hat{t}}}.$$

Equation (26):
Recall that $g(\hat{t}) \equiv \frac{\Psi + u(y_{\bar{t}}) - u(y_{\hat{t}})}{y_{\bar{t}} - y_{\hat{t}}}$.

$$\frac{dg(\hat{t})}{d\bar{b}} = \frac{u'(y_{\bar{t}})\dot{y}_{\bar{t}}\frac{d\bar{t}}{d\bar{b}} - u'(y_{\hat{t}})\dot{y}_{\hat{t}}\frac{d\hat{t}}{d\bar{b}}}{(y_{\bar{t}} - y_{\hat{t}})} - \frac{\Psi + u(y_{\bar{t}}) - u(y_{\hat{t}})}{(y_{\bar{t}} - y_{\hat{t}})^2} \left[\dot{y}_{\bar{t}}\frac{d\bar{t}}{d\bar{b}} - \dot{y}_{\hat{t}}\frac{d\hat{t}}{d\bar{b}}\right]$$

Substituting in (22) this can be written as

$$\begin{aligned}
\frac{dg(\hat{t})}{d\bar{b}} &= \frac{1}{y_{\bar{t}} - y_{\hat{t}}} \left[[u'(y_{\bar{t}})\dot{y}_{\bar{t}} - u'(y_{\hat{t}})\dot{y}_{\bar{t}}] \frac{d\bar{t}}{d\bar{b}} - [u'(y_{\hat{t}})\dot{y}_{\hat{t}} - u'(y_{\hat{t}})\dot{y}_{\hat{t}}] \frac{d\hat{t}}{d\bar{b}} \right] \\
&= \frac{\dot{y}_{\bar{t}}}{y_{\bar{t}} - y_{\hat{t}}} [u'(y_{\bar{t}}) - u'(y_{\hat{t}})] \frac{d\bar{t}}{d\bar{b}} \\
&= \frac{\dot{y}_{\bar{t}}}{y_{\bar{t}} - y_{\hat{t}}} [u'(y_{\bar{t}}) - u'(y_{\hat{t}})] \left(\frac{1}{y_{\bar{t}} - y_{\hat{t}}} + \frac{\dot{y}_{\hat{t}}(\bar{t} - \hat{t})}{y_{\bar{t}} - y_{\hat{t}}} \frac{d\hat{t}}{d\bar{b}} \right) \\
&= [u'(y_{\bar{t}}) - u'(y_{\hat{t}})] \frac{\dot{y}_{\bar{t}}}{(y_{\bar{t}} - y_{\hat{t}})^2} + \frac{\dot{y}_{\hat{t}}[u'(y_{\bar{t}}) - u'(y_{\hat{t}})]}{y_{\bar{t}} - y_{\hat{t}}} \frac{\dot{y}_{\bar{t}}(\bar{t} - \hat{t})}{y_{\bar{t}} - y_{\hat{t}}} \frac{d\hat{t}}{d\bar{b}} \\
&= [u'(y_{\bar{t}}) - u'(y_{\hat{t}})] \frac{\dot{y}_{\bar{t}}}{(y_{\bar{t}} - y_{\hat{t}})^2} + g'(\hat{t}) \frac{d\hat{t}}{d\bar{b}},
\end{aligned}$$

where the last equation is equation (26). From the second to third equality, we use the result in equation (24).

Equation (28)**:**
Solve the integral of equation (17)

$$\begin{aligned}
\bar{b} &= \int_{\hat{t}}^{\bar{t}} (y_t - y_{\hat{t}}) dt \\
&= \int_{\hat{t}}^{\bar{t}} (e^{g^y t} - y_{\hat{t}}) dt \\
&= \left[\frac{e^{g^y t}}{g^y} - y_{\hat{t}} t \right]_{\hat{t}}^{\bar{t}} \\
&= \frac{e^{g^y \bar{t}} - e^{g^y \hat{t}}}{g^y} - y_{\hat{t}}(\bar{t} - \hat{t}).
\end{aligned}$$

Divide by $y_{\hat{t}}$ and multiply by g_y

$$\begin{aligned}
\frac{g^y \bar{b}}{y_{\hat{t}}} &= \frac{y_{\bar{t}} - y_{\hat{t}}}{y_{\hat{t}}} - g^y(\bar{t} - \hat{t}) \\
&= u'(y_{\hat{t}})[y_{\bar{t}} - y_{\hat{t}}] - g^y(\bar{t} - \hat{t}).
\end{aligned}$$

Rewrite the equilibrium condition (22) and use it to substitute the first term on the right-hand of the equation. The equation then simplifies to

$$\begin{aligned}\frac{g^y \bar{b}}{y_{\hat{t}}} &= u(y_{\bar{t}}) - u(y_{\hat{t}}) + \psi - g^y(\bar{t} - \hat{t}) \\ &= \log(e^{g^y \bar{t}}) - \log(e^{g^y \hat{t}}) + \psi - g^y(\bar{t} - \hat{t}) \\ &= g^y \bar{t} - g^y \hat{t} + \psi - g^y(\bar{t} - \hat{t}) \\ &= \psi\end{aligned}$$

Use the functional form of the wage profile and solve for $\hat{t}$ to get

$$\begin{aligned}\frac{g^y \bar{b}}{e^{g^y \hat{t}}} &= \psi \\ e^{g^y \hat{t}} &= \frac{g^y \bar{b}}{\psi} \\ \hat{t} &= \frac{1}{g^y} \log\left(\frac{g^y \bar{b}}{\psi}\right).\end{aligned}$$

The last equality equals equation (28).

B Definitions of stationary equilibrium

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

Stationary equilibrium, exogenous prices

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 (12) 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 (13).

3. The quantity of the total housing stock is given by the total demand for housing services[32]

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

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

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

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

Stationary equilibrium, endogenous prices

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 (12) 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 (13).

3. The housing market clears:

$$\begin{aligned} H &= \bar{H} \\ \text{where} \quad H &= \sum_{\mathcal{J}} \Pi_j \int_U s_j(\mathbf{u}) d\Phi_j(U) \end{aligned}$$

and $\bar{H}$ is the housing stock from the equilibrium of the baseline economy.

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

4. Distributions of states Φ_j are given by the following law of motion for all $j < J$

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

C Computational method and solution algorithm

The computational method and the solution method are similar to those in Karlman et al. (2021). To summarize, we use the general generalization of the endogenous grid method G^{2}EGM 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.

D Labor income process

D.1 Data sample

Equation (1) is estimated using PSID data, survey years 1970 to 1992. The variable definitions and sample restrictions are the same as in Karlman et al. (2021).

D.2 Estimation

In this section, we describe how the exogenous earnings process in equation (1) 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 log of household i's earnings less the household fixed component $\hat{\alpha}_i$ and the deterministic life-cycle component.

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

where the equality follows from equation (1). Define r_{id} as household i's d-period difference in $\log(y^*_{ij})$,

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

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

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

These variances are estimated by running an OLS regression of $\text{Var}(r_{id}) = r^2_{id}$ on d, including a constant term. The estimate of the variance of the permanent shock is given by the coefficient of d, and the estimate of the variance of the transitory shock is equal to the constant term divided by two. The estimate of the variance of the household fixed-effect component of earnings $\hat{\sigma}^2_\alpha$ is given by the residual variance in period $j = 1$,

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

E Additional results

E.1 Effects on house sizes

In the main analysis, we find that households postpone buying a house when the down-payment requirement is stricter. An alternative way that households can adapt to the stricter mortgage regulation is by buying a cheaper house, and thereby lowering the required down payment. Figure 12 shows the mean house size (quality) among those who own in both the baseline setting and in the economy with a down-payment constraint of 40 percent. Most attention should be paid to ages 35 to 55, since there are almost no homeowners younger than 35 when the required down payment is 40 percent, as illustrated in Figure 6. For almost all ages, households own larger homes when lending standards

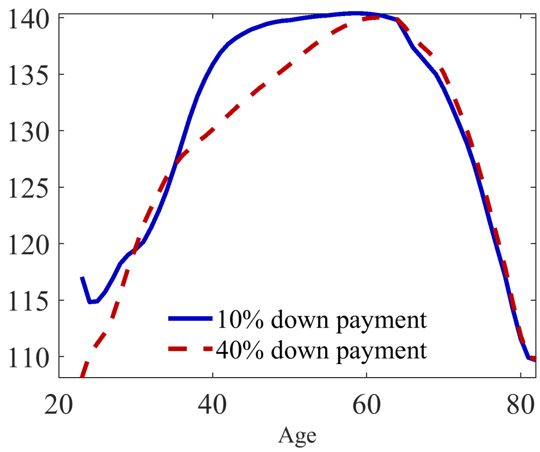


Figure 12: Mean house size (quality) conditional on owning in both equilibria, over the life cycle

are more lax. Hence, there is also an intensive-margin response to the policy change, in the sense that house buyers choose cheaper houses, at least when they first enter homeownership.

E.2 Fixed-housing supply

The results in Section 5 were derived under the assumption that changes in the down-payment constraint have no long-run impact on house and rental prices. This is equivalent to assuming that the supply of housing in perfectly elastic in the long run, which we believe is a realistic assumption. However, for robustness, we instead make the opposite assumption in this section. We let the supply of housing be perfectly inelastic, and solve for the house price that clears the housing market. We solve the model under a wide range of down-payment requirements and compare our results to those under perfectly elastic housing supply.

Figure 13 plots the mean MPC and the share of wealthy and poor HtM households for different down-payment requirements. The results are both qualitatively and quantitatively very similar to the results under elastic housing supply, as shown in Figure 7. The reason behind this result is the weak link between the thightness of mortgage-lending standards and prices. This finding of a modest price response is not new, and we refer the reader to Kaplan et al. (2020) for an in-detail discussion. Essentially, the primary consequence of stricter lending standards is that households are pushed out of ownership into renting. However, this is mainly a change in the way households obtain housing services and there are only small effects on the quantity of housing demanded. This implies that the equilibrium price does not change much. Given the weak effect on prices, the absolute size of the down payment required is roughly the same whether prices are allowed to change

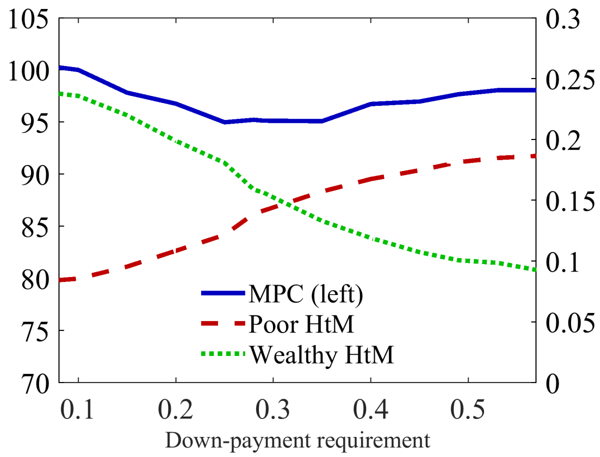


Figure 13: Mean MPC (percent of baseline) and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, under the assumption of perfectly inelastic housing supply

or not. For this reason, the effects of stricter down-payment constraints on households' choices and their MPCs, are similar under the different assumptions on the housing-supply elasticity.

E.3 Varying the shock size

In the core analysis of this paper we focus on the consumption response to a negative income shock. However, the size and sign of the shock is set somewhat arbitrarily. For this reason, this section explores if our main results depend on the size and sign of the exogenous income shock that is used to compute the MPCs.

Figure 14 displays the mean MPC across different down-payment constraints, where the shock is varied from negative 4 000 dollars to positive 10 000 dollars. The second highest line, corresponding to the negative shock of 1 000 dollars, is the same as in Figure 7. Two things can be noted. First, there is a clear negative relationship between the size of the shock and the mean MPC. This is reasonable, as a negative shock pushes households closer to the credit constraints, whereas a positive shock moves the households away from the constraints. Quantitatively, this relationship is not large, but also not entirely insignificant. For the largest negative shock the average MPC is just below 0.2 when the down-payment constraint is 0.10. When we instead consider a positive shock of 10 000 dollars, the mean MPC falls around 10 percent to just below 0.18. Second, we see that the U-shaped relationship between the down-payment requirement and the mean MPC is robust. Even when we consider a positive shock of 10 000 dollars, the shape of the graph is largely unchanged.

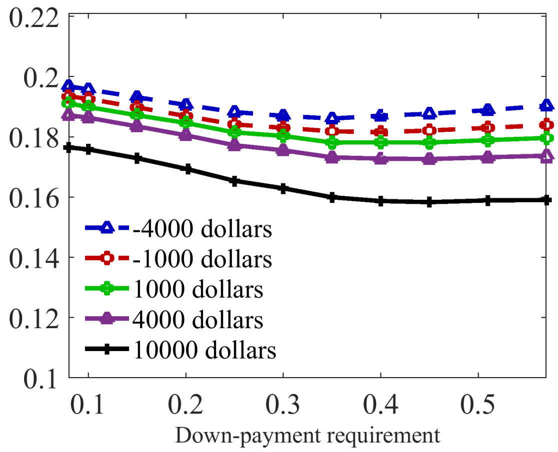
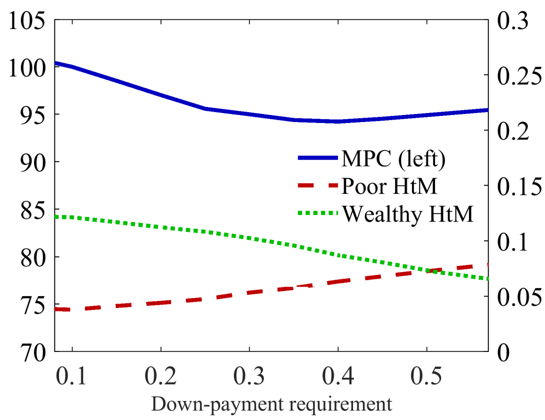


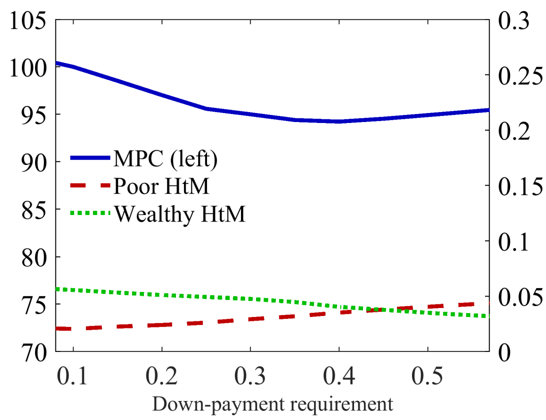
Figure 14: Mean MPC across various down-payment requirements for positive and negative shocks of different sizes

E.4 Alternative definitions of hand-to-mouth

Throughout the paper, we have labeled a household with an MPC greater than 0.3 as a HtM household. This threshold was chosen somewhat arbitrarily, so in this section we explore the robustness of our findings with respect to the definition of hand-to-mouth. Figure 15a and 15b show the share of poor and wealthy HtM households across different down-payment requirements, where being HtM is defined as having an MPC above 0.5 and 0.7, respectively. With the stricter definitions, there are of course fewer HtM households. However, the main results of the paper still hold. When the down-payment constraint is stricter, households postpone their house purchase, resulting in fewer wealthy HtM households and more poor HtM. The mean MPC is of course not affected by the definition of HtM.



(a) Defining HtM as $MPC_{ij} > 0.5$



(b) Defining HtM as $MPC_{ij} > 0.7$

Figure 15: Mean MPC (percent of baseline) and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements

E.5 Lowering transitory risk

Households with high MPCs typically have very little or no liquid savings. The decision to hold liquid savings depends on the perceived nature of income risk. Since the income process can be specified in many ways, it is interesting to consider a different form of income risk to see if our main results still hold. In this section, we do this by reducing the variation of the transitory income shock by setting its standard deviation to half that of the baseline calibration.

The income process still has the same age-specific component, but when the variance of the transitory shock is lower we need to re-estimate the variance of both the permanent shock and the household fixed component. This is done such that the cross-sectional variance of income at each age is unchanged. Let $\sigma_y^2(j)$ denote the variance of income at age j. Then the variance at the first and last periods of working age can be expressed as

$$\sigma_y^2(1) = \sigma_\alpha^2 + \sigma_\eta^2 + \sigma_\upsilon^2$$
$$\sigma_y^2(J_{ret}) = \sigma_\alpha^2 + J_{ret} * \sigma_\eta^2 + \sigma_\upsilon^2.$$

Both the variance of income at each age and the transitory-shock variance σ_υ^2 are known. Hence, we have a two-equation system with two unknowns. The variance of the two shocks can be solved for as

$$\sigma_\eta^2 = \frac{\sigma_y^2(J_{ret}) - \sigma_y^2(1)}{J_{ret} - 1} \tag{30}$$
$$\sigma_\alpha^2 = \sigma_y^2(1) - \sigma_\eta^2 - \sigma_\upsilon^2. \tag{31}$$

The estimated variances are presented in table 4.

Parameter	Description	Value
σ_α^2	Fixed effect	0.202
σ_η^2	Permanent	0.012
σ_ν^2	Transitory	0.015

Table 4: Estimated variances of earnings shocks, assuming lower transitory risk
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.

With a different income process, the model needs to be recalibrated to match the targeted moments. The resulting calibration is shown in Table 5.

Figure 16 illustrates the relationship between the required down payment and the mean MPC and the shares of HtM households. The results are qualitatively similar to the baseline model, but quantitatively stronger. The reason is that less transitory risk lowers

Parameter	Description	Value	Target moment	Data	Model
α	Consumption weight in utility	0.759	Median house value-to-earnings, age 23–64	2.29	2.29
β	Discount factor	0.957	Mean net worth, over mean earnings age 23–64	1.40	1.41
υ	Strength of bequest motive	3.4	Mean net worth age 75 over mean net worth age 50	1.67	1.65
Ψ	Utility bonus of owning	0.28	Mean own-to-rent size	1.80	1.73
δ^r	Depreciation rate, rentals	0.056	Homeownership rate, age 30–40	0.58	0.56
$\underline{h}$	Minimum owned house size	164	Homeownership rate, all ages	0.67	0.68
ς^r	Refinancing cost	1.59	Refinancing share, homeowners	0.08	0.08
λ	Level parameter, tax system	1.698	Average marginal tax rates	0.13	0.13
τ^p	Progressivity parameter	0.142	Distribution of marginal tax rates	N.A.	N.A.

Table 5: Internally calibrated parameters, under lower transitory income risk

Note: Parameters calibrated to match model moments to their counterparts in the data. The first two columns list the parameters and their descriptions. The third column shows the calibrated parameter values. The fourth column contains the descriptions of the targeted moments, while column five lists their respective values in the data. Finally, the last column states the values of the corresponding model moments, achieved by using the parameter values in column three. The minimum owned house size $\underline{h}$ and the fixed refinancing cost ς^r are in 1000's of 2019 dollars.

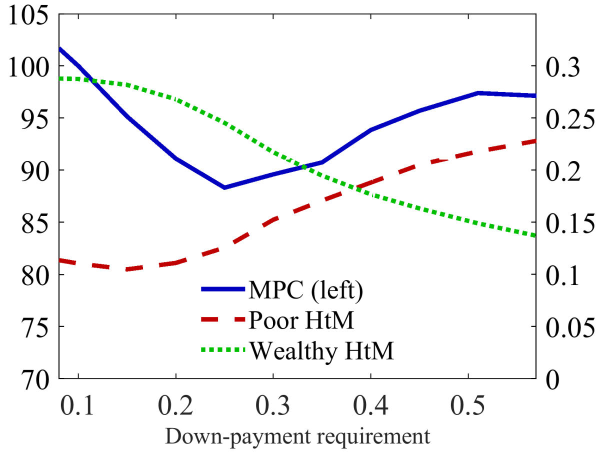


Figure 16: Mean MPC (percent of baseline) and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, in a setting with less transitory income risk

the precautionary savings motive, meaning there are more constrained households that are affected by the policy change. The mean MPC is again U-shaped, but the minimum is achieved at a somewhat smaller down-payment constraint than in the baseline calibration. The reduction in the mean MPC is over 10 percent at the minimum, as opposed to 5 percent in the baseline.

E.6 Increasing the baseline down-payment constraint

In our baseline calibration of the model to the U.S. economy we set the down-payment requirement to 10 percent. This choice was made to make sure that the model captures the non-negligible number of homeowners with a loan-to-value ratio of close to 90 percent.

However, since there is no hard requirement stipulated in federal laws or regulations, this calibration choice is not obvious. To test if this choice affects the main results of the paper, we here assume a 20 percent down-payment requirement when calibrating the model. This is consistent with, e.g., Sommer and Sullivan (2018). The new calibration is shown in Table 6.

Parameter	Description	Value	Target moment	Data	Model
α	Consumption weight in utility	0.752	Median house value-to-earnings, age 23–64	2.29	2.29
β	Discount factor	0.943	Mean net worth, over mean earnings age 23–64	1.40	1.38
υ	Strength of bequest motive	5	Mean net worth age 75 over mean net worth age 50	1.67	1.65
Ψ	Utility bonus of owning	0.3	Mean own-to-rent size	1.80	1.94
δ^r	Depreciation rate, rentals	0.062	Homeownership rate, age 30–40	0.58	0.57
$\underline{\mathrm{h}}$	Minimum owned house size	182	Homeownership rate, all ages	0.67	0.67
ς^r	Refinancing cost	2.61	Refinancing share, homeowners	0.08	0.08
λ	Level parameter, tax system	1.698	Average marginal tax rates	0.13	0.13
τ^p	Progressivity parameter	0.142	Distribution of marginal tax rates	N.A.	N.A.

Table 6: Internally calibrated parameters

Note: Parameters calibrated to match model moments to their counterparts in the data. The first two columns list the parameters and their descriptions. The third column shows the calibrated parameter values. The fourth column contains the descriptions of the targeted moments, while column five lists their respective values in the data. Finally, the last column states the values of the corresponding model moments, achieved by using the parameter values in column three. The minimum owned house size $\underline{\mathrm{h}}$ and the fixed refinancing cost ς^r are in 1000's of 2019 dollars.

The main results are summarized in Figure 17. The alternative calibration does not change our findings qualitatively. When the down-payment constraint is stricter, households postpone their house purchase, resulting in fewer wealthy HtM households and more poor HtM. The mean MPC is again U-shaped in the required down payment. The minimum is achieved at a down-payment constraint of approximately 40 percent, but this is consistent with a reduction of mean MPC of roughly 7 percent from its current level, which is somewhat larger than the 5 percent reduction in the main analysis.

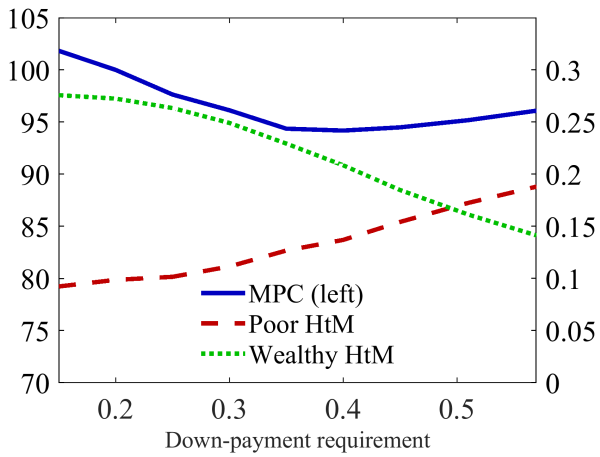


Figure 17: Mean MPC (percent of baseline) and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, setting $\theta = 0.2$ in the baseline calibration

E.7 Lowering the refinancing cost

The decision to hold precautionary savings in the liquid asset depends not only on the degree and type of risk that the household faces, but also on how illiquid the alternative asset is. In this setting, the alternative to using bonds to insure against idiosyncratic risk is to use housing equity by using cash-out refinancing. Therefore, it is of interest to study how the main conclusions of the paper depends on how illiquid housing equity is. To do this, we re-do the main exercise of the paper for an alternative calibration where the refinancing cost is halved. The model is then recalibrated to match the same moments as before, except that the share of households who refinance in every period is left untargeted. The calibration is summarized in Table 7, and the main results are illustrated in Figure 18.

Parameter	Description	Value	Target moment	Data	Model
α	Consumption weight in utility	0.762	Median house value-to-earnings, age 23–64	2.29	2.29
β	Discount factor	0.953	Mean net worth, over mean earnings age 23–64	1.40	1.41
υ	Strength of bequest motive	4.2	Mean net worth age 75 over mean net worth age 50	1.67	1.61
Ψ	Utility bonus of owning	0.3	Mean own-to-rent size	1.80	1.80
δ^r	Depreciation rate, rentals	0.056	Homeownership rate, age 30–40	0.58	0.58
$\underline{h}$	Minimum owned house size	180	Homeownership rate, all ages	0.67	0.67
λ	Level parameter, tax system	1.698	Average marginal tax rates	0.13	0.13
τ^p	Progressivity parameter	0.142	Distribution of marginal tax rates	N.A.	N.A.

Table 7: Internally calibrated parameters

Note: Parameters calibrated to match model moments to their counterparts in the data. The first two columns list the parameters and their descriptions. The third column shows the calibrated parameter values. The fourth column contains the descriptions of the targeted moments, while column five lists their respective values in the data. Finally, the last column states the values of the corresponding model moments, achieved by using the parameter values in column three. The minimum owned house size $\underline{h}$ and the fixed refinancing cost ς^r are in 1000's of 2019 dollars.

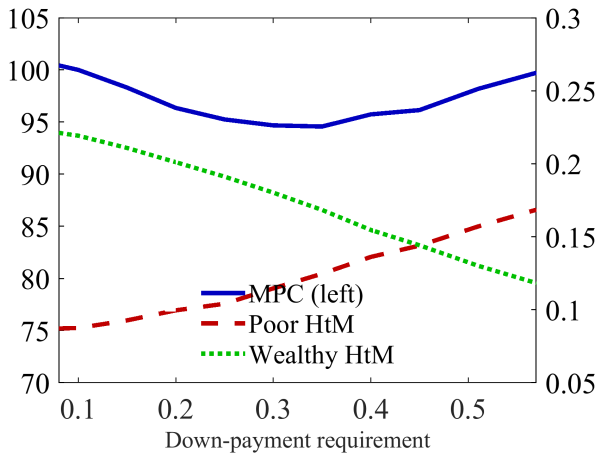


Figure 18: Mean MPC (percent of baseline) and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, setting the refinancing cost to 1267 dollars in the baseline calibration

E.8 Lowering the calibrated PTI-requirement

While this paper has focused exclusively on the down-payment requirement, the model also features another constraint that is arguable of similar importance in the mortgage market: the payment-to-income requirement. This section looks at how the tightness of the PTI-requirement interacts with the main result of the paper. We do this by lowering the PTI-requirement by ten percent, from $\phi = 0.177$ to 0.1593. The model is then recalibrated to match the same moments are before. The calibration is summarized in Table 8, and the main result is summarized in Figure 19.

Parameter	Description	Value	Target moment	Data	Model
α	Consumption weight in utility	0.745	Median house value-to-earnings, age 23–64	2.29	2.28
β	Discount factor	0.949	Mean net worth, over mean earnings age 23–64	1.40	1.42
υ	Strength of bequest motive	4.2	Mean net worth age 75 over mean net worth age 50	1.67	1.69
Ψ	Utility bonus of owning	0.3	Mean own-to-rent size	1.80	1.86
δ^r	Depreciation rate, rentals	0.062	Homeownership rate, age 30–40	0.58	0.56
$\underline{h}$	Minimum owned house size	179	Homeownership rate, all ages	0.67	0.67
ς^r	Refinancing cost	2.42	Refinancing share, homeowners	0.08	0.08
λ	Level parameter, tax system	1.698	Average marginal tax rates	0.13	0.13
τ^p	Progressivity parameter	0.142	Distribution of marginal tax rates	N.A.	N.A.

Table 8: Internally calibrated parameters

Note: Parameters calibrated to match model moments to their counterparts in the data. The first two columns list the parameters and their descriptions. The third column shows the calibrated parameter values. The fourth column contains the descriptions of the targeted moments, while column five lists their respective values in the data. Finally, the last column states the values of the corresponding model moments, achieved by using the parameter values in column three. The minimum owned house size $\underline{h}$ and the fixed refinancing cost ς^r are in 1000's of 2019 dollars.

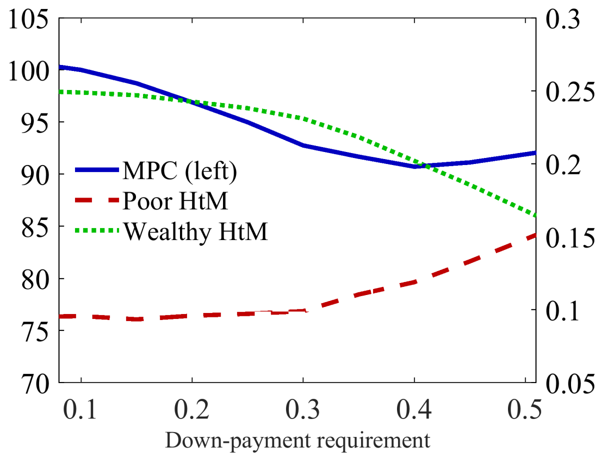


Figure 19: Mean MPC (percent of baseline) and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, setting $\phi = 0.1593$ in the baseline calibration

The qualitative conclusion of the paper still holds, with a U-shaped average MPC that has a minimum around 0.4. The main difference from the baseline calibration is that the share of poor- and wealthy hand-to-mouth agents are not as affected by the down-payment requirement, especially at low levels. The reason is that with a stricter PTI-requirement, the down-payment requirement is less likely to be the binding constraint. Therefore, the effect is weaker initially. However, once we look at a situation where the required down payment is 25 percent of the house value or more, the down-payment again becomes very important in shaping how many households are constrained.

E.9 A proportional income shock

Much of the focus of this paper is on the consumption response to a negative income shock of 1000 dollars. However, the relevant shocks are unlikely to be uniformly distributed like this. Moreover, we have also seen that stricter lending standards have little effect on the average MPC, but a substantial effect on the distribution of MPCs. For that reason, here we again study how the average MPC is affected by an unexpected transitory income shock, but assume that the shock is proportional. Feeding in a one percent decrease in earnings for all working age households, we get the aggregate consumption response presented in figure 20.

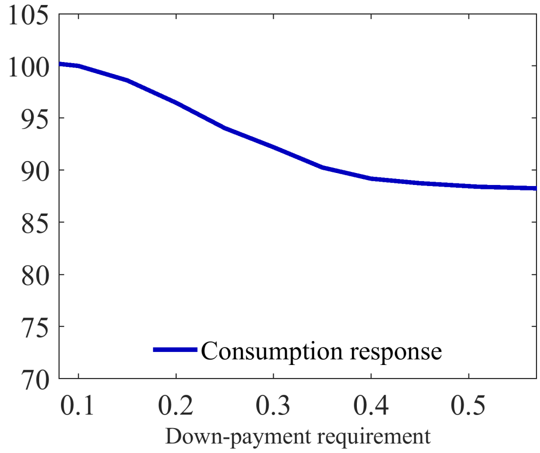


Figure 20: Response of aggregate consumption to a 1 % shock to income. The response is normalized to 100 for the baseline calibration.

A stricted down-payment requirement leads to a smaller consumption response. The effect is fairly large, with the reponse being roughly 10 percent smaller with a 30 percent down payment compared to the baseline requirement of 10 percent. This is more than double the response compared to the case where all household received the same absolute amoung. The underlying reason is that high-earning households see their MPCs fall as the constraint is tightened. Since they receive the largest transfers in this exercise, they are also the ones who drive the aggregate dynamics.