Down-payment requirements and consumption responses to income shocks

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Abstract

This paper studies how down-payment requirements for house purchases affect household consumption. We show that the marginal propensity to consume (MPC) increases for some households and decreases for others as a result of stricter down-payment regulations, which stands in sharp contrast to the positive relationship between MPC and a traditional borrowing constraint. We also show that the mean MPC in the economy is U-shaped in the down-payment constraint, a finding that rests on an important interaction with the traditional borrowing limit. To quantify this relationship, we construct an incomplete-markets heterogeneous-household model, calibrated to the U.S. economy. We find that the mean MPC is minimized at a down-payment constraint of 40 percent, which is associated with a 5 percent reduction in the mean MPC from its current level. Moreover, we show that the effectiveness of monetary policy is reduced under stricter down-payment requirements and fiscal transfers have a larger impact if targeting low-income households.

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

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1 Introduction

Following the Great Recession, many countries have implemented stricter borrowing standards. In particular, households are now often required to pay a considerable down payment when purchasing a home. For example, only 10 percent of the countries in the European Economic Area (EEA) had a limit on the share of the house value that can be financed with a mortgage in 2010, whereas almost 80 percent had a loan-to-value (LTV) constraint in place in 2021 (see Figure 1). LTV requirements also play a prominent role in, e.g., the U.S., Canada, New Zealand, and Australia.

As the required down payments are often sizable, they may significantly affect households' savings and consumption behavior. Yet, we know surprisingly little about the way in which households respond to down-payment constraints. As the distribution of households' savings has been shown to be key for understanding, e.g., aggregate consumption responses to adverse shocks, as well as effectiveness of monetary and fiscal policy, there is a need to better understand how changes in the down-payment requirement influence these choices. The purpose of this paper is to fill some of this gap.

In this paper, we analyze how down-payment requirements affect households' marginal propensity to consume (MPC) and how the changes to individual consumption behavior impact aggregate consumption responses and effectiveness of macroeconomic policies. To this end, we use a life-cycle model and study the distribution of MPCs across a wide range of values of the down-payment constraint. The paper makes three main contributions. First, we show that in contrast to a traditional borrowing limit that weakly increases

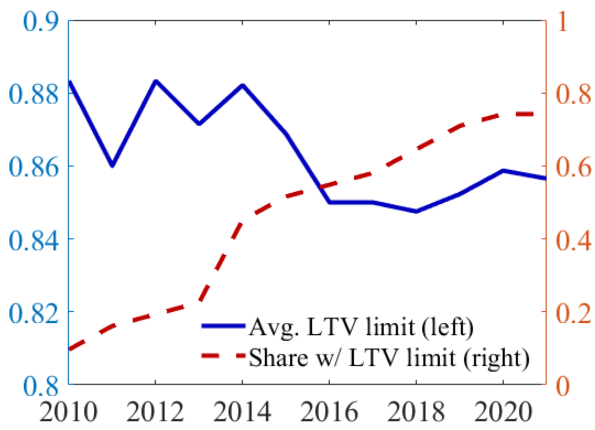


Figure 1: Prevalence of LTV limits among European countries

Note: The data is for all countries in the European Economic Area, which consists of the European Union along with Norway and Iceland. The United Kingdom, which was a member until 2021, is also included in the sample.
Source: European System of Financial Supervision

MPCs, a stricter down-payment requirement causes some households' MPC to increase and others' to decrease. A stricter down-payment constraint makes households postpone buying a house. On the one hand, this leads to a reduction in the share of wealthy hand-to-mouth (HtM) households, as older households have more liquid savings. On the other hand, the number of poor HtM households increases as it becomes optimal for young households to delay savings for the down payment to periods in life where income is higher. Second, we show that the mean MPC is U-shaped in the down-payment constraint. We highlight that this result relies on an interaction between the required down payment and the availability of unsecured debt. Third, we find that the cash-flow channel of monetary policy is reduced and that fiscal transfers directed at young households with low income are relatively more effective when the down-payment constraint is more strict.

We begin by developing a simple two-period model that conceptually clarifies how a down-payment requirement differs from a traditional borrowing constraint. This model is a standard household problem of consumption and savings, appended with a traditional borrowing constraint as well as a savings threshold for receiving a utility bonus. The traditional borrowing limit restricts borrowing such that households with relatively low income in the first period are unable to fully smooth consumption. These households have limited savings and high MPCs, i.e., they are so called poor HtM households. The savings threshold, on the other hand, resembles the down payment required to buy a house and thereby receive the additional benefit associated with ownership. This threshold creates a trade-off, where households with high enough income are willing to give up consumption in the first period in order to receive the utility bonus. Since these households deviate from perfect consumption smoothing, they respond strongly to any transfer in the first period and have high MPCs, despite having positive wealth. Hence, in this simple model we have both poor and wealthy HtM households, as described in Kaplan and Violante (2014).

When the traditional borrowing constraint is made stricter we see that more households are constrained in their spending in the first period. Hence, a stricter borrowing constraint unambiguously increases the mean MPC. However, a stricter down-payment requirement, i.e., a higher savings threshold to receive the utility bonus, has an ambiguous effect on the mean MPC. The larger threshold makes it more costly to obtain the utility bonus for the already constrained households, some of which are discouraged from saving the required amount. As these households are no longer constrained by the down-payment requirement, they contribute to a reduction of the share of wealthy HtM households. However, the stricter constraint also affects some previously unconstrained households. Specifically, households who previously saved more than the old constraint, but now choose to save more in order to comply with the new constraint, contribute to an increase in share of wealthy HtM households. As a result, there is a shift in the composition of the wealthy HtM towards higher-income households, and the net effect on mean MPC is unclear.

Since housing tenure and mortgage choices are strongly linked to age, we proceed by extending the two-period model to incorporate a full life cycle, where earnings increase with age up until retirement. The main insights from the two-period model also apply in the life-cycle model, namely, that some households trade-off consumption smoothing against the additional benefit of owning a house. In addition, the richer model allows us to identify how savings dynamics over the life cycle are affected by adjustments of the down-payment requirement. Specifically, we see that a stricter down-payment constraint causes households to postpone buying a home until later in life. This choice results in fewer homeowners and thereby fewer wealthy HtM households. On the other hand, the choice to postpone buying a house also makes it optimal to save less early in life, when it is the most costly. As it is preferable to concentrate savings in periods when earnings are higher, there is a larger share of young households with little savings who are constrained by the limit on unsecured debt. Hence, this latter effect hinges on the presence of an occasionally binding traditional borrowing constraint — highlighting an important interaction between secured and non-secured borrowing restrictions.

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. We find that the mean MPC is U-shaped in the down-payment requirement. If the constraint is tightened from a relatively lax level, the reduction in the share of wealthy HtM dominates the increase in the share of poor HtM; whereas the opposite holds when increasing the constraint from already strict levels.

To quantify the effects of stricter down-payment limits in the U.S. setting, we construct a rich life-cycle model with heterogeneous households and where mortgage and housing markets are explicitly modeled. Markets are incomplete in the sense that 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, but also in housing. Importantly, housing equity is illiquid. First, there are transaction costs associated with both buying and selling a house. Second, there are LTV and 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 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.[1]

[1] We compute MPC as the change in non-durable consumption in response to an unexpected shock to

Portfolio choices, both in terms of leverage and liquid bond holdings, play an important role in determining households' MPC. A significant portion of renters hold no or very little liquid 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.[2] Again, we see that households postpone buying a house when the constraint is made stricter, resulting 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 depends on which effect dominates, which in turn depends on how strict the constraint is to begin with. We find that 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.

A stricter down-payment requirement also has implications for the effectiveness of monetary and fiscal policy. We find that although a stricter down-payment constraint can reduce the mean MPC in the economy, it also 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 a stricter down-payment requirement makes transfers to low-income and young households relatively more effective, as these households' MPCs increase.

Our paper mostly speaks to the literature on borrowing constraints. Several influential papers have pointed out the role of borrowing limits for different households' consumption choices, see, e.g., Bewley (1977), Krusell and Smith (1998), and Scheinkman and Weiss (1986). More specifically, we relate to the literature on the effects of down-payment requirements. A number of papers study down-payment constraints in the context of business-cycle analysis. Greenwald (2018) finds that PTI requirements are more effective than LTV limits in counteracting cyclicality, and highlights their role in the Great Recession. Our model includes a richer heterogeneity among households, which allows us to explore differences in consumption responses across households. On the empirical side,

available resources (cash-on-hand), relative to the size of the shock. In line with the common practice in the literature, we use the word *marginal* even though we consider shock sizes that are relatively large. Furthermore, to focus on the direct effects on demand, we abstract from possible propagation mechanisms through changes in, e.g., prices caused by the shocks.

[2]In our main experiments we assume that housing supply is fully flexible, such that there is no effect on house prices. In a robustness exercise we consider the other extreme where housing supply is fixed, and house prices adjust endogenously to clear the housing market, and the main results are qualitatively the same.

Lim et al. (2011) perform cross-country regressions and find that stricter down-payment limits are linked to a lower cyclicality of debt. Acharya et al. (2020) and Peydro et al. (2020) find that stricter LTV constraints in Ireland and the U.K., respectively, lead to reduced credit and house-price growth. 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.

Our paper also relates to the literature that studies households' MPCs. Most empirical studies show that households' MPCs are much higher than the permanent income hypothesis suggests (Agarwal and Qian, 2014; Fagereng et al., 2021; Parker et al., 2013). Fagereng et al. (2021) also show that liquid assets and age are important determinants of consumption responses, which our model is consistent with. A growing strand of literate explores the theoretical mechanisms behind high MPCs. Differences in liquidity across asset classes have been emphasized to play an important role (Kaplan et al., 2014). In their seminal work, Kaplan and Violante (2014) show that when incorporating an illiquid asset in the analysis, wealthy households can also have high MPCs, as observed in the data. We focus our attention on one specific type of illiquid asset, housing, and construct a model with detailed housing and mortgage markets to consider changes in the down-payment requirement. 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.

The importance of the cash-flow channel of monetary policy is 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 depends on the level of the down-payment requirement. 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. Ferrero et al. (2018)

focus on the interaction between LTV requirements and monetary policy, and find that the optimal LTV limits are countercyclical. 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, there is a rich literature that studies the causes of the Great Recession and the role of relaxed lending standards, see, e.g., Mian and Sufi (2014). A prominent result in this line of work is that the rise in household debt in the early 2000's led to stronger consumption responses among households when the crisis hit. Moreover, households with more debt were found to cut back on consumption to a greater extent (Andersen et al., 2017; Bunn and Rostom, 2015; Dynan et al., 2012; Kovacs et al., 2018; Mian et al., 2013). However, as highlighted in, e.g., Andersen et al. (2017) and Baker (2018), the build up of debt prior to an income shock, rather than debt levels per se, is an important determinant of these consumption responses. Thus, our paper does not contradict these findings, but we instead focus on the long-run implications of changing the accessibility of debt.

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' MPC. In Section 3, we proceed by constructing a model of the U.S. economy, which is calibrated and compared to the data in Section 4. Before presenting our main results in Section 5, we validate the quantitative model by comparing the model performance to empirical findings of the short-run effects of stricter down-payment requirements. Section 6 concludes the paper.

2 Down-payment requirements in a simple framework

To characterize the relationship between the down-payment requirement and households' consumption and savings decisions, this section studies a simple extension of a standard consumption-savings problem. Before we turn to a quantitative analysis where the housing and mortgage markets are modeled explicitly, we consider a setting 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.

2.1 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.[3] For tractability, 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

$$\max_{c_1,c_2,b} U(c_1) + U(c_2) + \mathbb{I}\Psi \; s.t.$$

$$c_1 = y_1 - b$$

$$c_2 = y_2 + b$$

$$y_1 + y_2 = 1$$

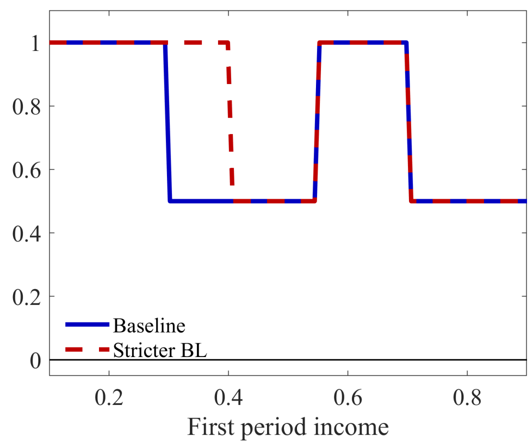
$$b \geq \underline{b}$$

$$\mathbb{I} = \begin{cases} 1 \text{ if } b \geq b^* \\ 0 \text{ else.} \end{cases}$$

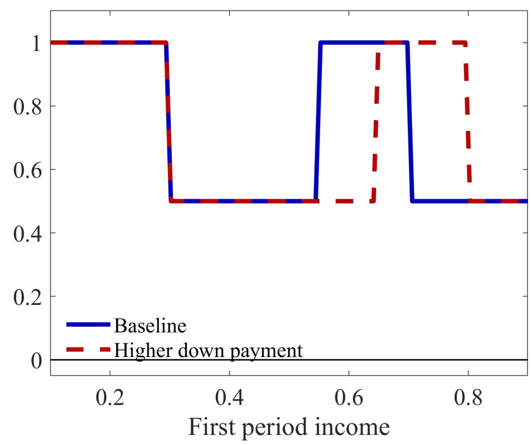
The solid line in Figure 2 shows how the MPC in the first period varies across different levels of first-period income y_1 in our baseline scenario. Four types of households emerge. First, we have the poor renters. These are households with very low first-period income, who ideally would like to borrow more than $\underline{b}$ 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

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

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 2: 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 2a 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.

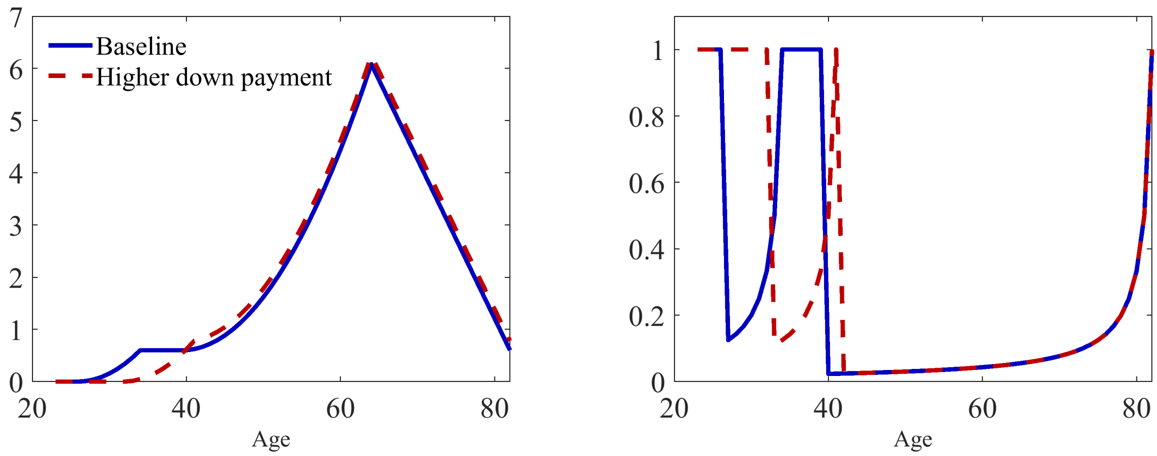
The dashed line in Figure 2b illustrates households' MPC when we instead increase the down-payment requirement. In contrast to the case of a stricter borrowing constraint, the mean MPC can increase *or* decrease in response to a stricter down-payment requirement. On the one hand, some households no longer 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.

2.2 Down-payment constraints and life-cycle savings

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 may affect the timing of housing purchases. We will demonstrate that this mechanism is key to include, as the decision of when to buy a house is crucial for households' savings dynamics and MPCs.

Consider a stylized life-cycle model where age is the only source of heterogeneity. Households are born at age 23, work until age 64, and die with certainty at age 83. Households face an upward-sloping income profile, and receive benefits during retirement. For simplicity, and to roughly mimic a typical earnings profile from the data, we assume that earnings grow linearly and is doubled during working age. The replacement rate during retirement is set to one half of earnings in the last working-age period. The other features of the model are the same as in the two-period version, i.e., households choose consumption and savings in risk-free bonds, and there is a borrowing constraint $\underline{b}$, which we set to zero, and a down-payment requirement b^* that is modeled as a savings threshold for receiving a per-period utility bonus. We normalize life-time earnings such that the average income is one, implying that the size of the down-payment requirement can be interpreted as a share of average earnings.

The solid lines in Figure 3 show savings and MPCs over the life cycle in our baseline setting. Just like in the two-period model, households trade off the cost of deviating from consumption smoothing against the benefit of receiving the utility bonus. In the two-period model, this trade-off was decisive for whether a household purchased a home or not. In the life-cycle model, the trade-off instead affects when it is optimal to become a homeowner. Buying a house at an early age requires forgoing consumption in order to finance the down payment. For young households with low earnings, the cost of saving for the down payment exceeds the benefit as their consumption is already limited. These households instead choose to be at the borrowing limit and consequently behave as poor HtM households with an MPC of 1. They are depicted to the left in Figure 3. Over time their earnings increase, and eventually the benefit of saving up for the down payment exceeds the cost of lowering consumption. The households start to accumulate wealth and become unconstrained renters with relatively low MPCs. At some point, households' savings reach the required down payment and they become homeowners. Any additional savings are now driven entirely by the desire to smooth consumption over the life cycle. Therefore, households who have recently bought a house do not want to increase their savings further. As their savings are too high to smooth consumption perfectly, they are the wealthy HtM households with an MPC of 1, and explain the first kink in the savings plot. As earnings increase further, households' optimal savings exceed the down-payment requirement and households become unconstrained owners. As households in the model have no bequest motive, the MPC increases when they approach the end of life.[4]



(a) Savings

(b) MPC

Figure 3: Savings and MPC over the life-cycle, in a stylized life-cycle model

The dashed lines in Figure 3 illustrate how the life-cycle patterns of savings and MPCs change when the down-payment constraint is made stricter. A stricter policy makes it more costly for young households to become homeowners, as it requires them to save more and consume less in the early stages of life. In order to avoid lowering consumption when young, it becomes optimal for these households to postpone their house purchase. The choice to delay becoming a homeowner means that house buyers are now older and have higher income. This also means that their savings motive for retirement is

[4] We assume that households die with a house, i.e., savings equal to the down-payment requirement.

stronger. As a result, the optimal savings of the house buyers soon exceed even the new, stricter down-payment requirement, resulting in fewer wealthy HtM households. With the postponed house purchase, it is also better to concentrate savings in later periods when it is less costly in terms of forgone consumption. Consequently, households wait longer before they start to accumulate wealth. As households spend a larger fraction of their life at the borrowing limit, the share of poor HtM households increases. Since the share of poor HtM households increases and the share of wealthy HtM decreases, a stricter down-payment requirement has an ambiguous effect on mean MPC.

Figure 4 shows that the effects depicted in Figure 3 hold for a large set of down-payment constraints. The share of wealthy HtM households is high for low levels of the requirement and decreases when the constraint is tightened, as households postpone their house purchases. The share of poor HtM households is low to begin with, but increases as young households stop saving for housing purposes when the constraint is made stricter.

A key result in Figure 4 is that the mean MPC is U-shaped in the down-payment requirement. Hence, the effect on mean MPC of making the down-payment constraint stricter depends on how tight the constraint is to begin with. At low levels of the constraint, almost all households save enough for the down payment. A stricter constraint causes some households to postpone the house purchase, which decreases the share of wealthy HtM. However, few of these households become poor HtM households, as they still find it worthwhile to save for the future house purchase. If the constraint on the other hand is tightened from a relatively high level, the share of 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 further postponements of homeownership make it increasingly unattractive to save for young households with relatively low earnings.

In the model, it also becomes clear that there is an interesting interaction between the down-payment requirement and the standard borrowing constraint. In fact, the U-shape of the mean MPC is a direct result of this interaction. When the down-payment constraint increases, some of the young households no longer save for housing purposes. If there is a borrowing constraint, then these households can become poor HtM households with high MPCs. However, if there is no borrowing constraint, they would instead borrow against future income, and thereby be unconstrained renters with modest MPCs. As a result, there would be no push towards a higher mean MPC in response to a stricter down-payment limit, and the mean MPC would be weakly decreasing with the constraint. Thus, changes to the down-payment requirement need to be studied in tandem with a relevant borrowing constraint.

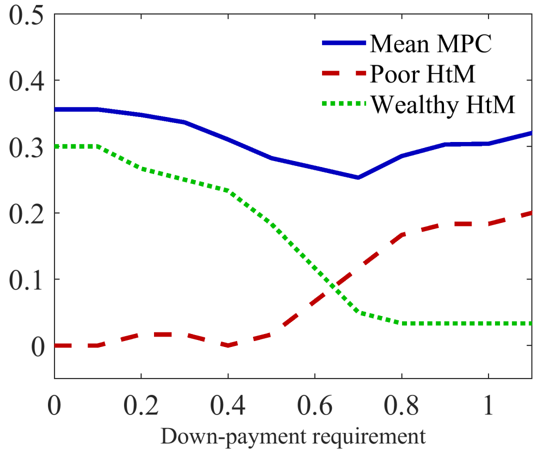


Figure 4: Mean MPC and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements

Note: In the simple life-cycle model, the down-payment requirement is a share of average earnings, which are normalized to 1.

We conclude that with an occasionally binding traditional borrowing constraint, making the down-payment requirement stricter lowers the share of wealthy HtM households and increases the share of poor HtM households. The overall effect on mean MPC depends on the relative strength of these two off-setting forces and therefore also on the prevalence of different types of households in the economy. Thus, a comprehensive understanding of the effects of a stricter down-payment requirement can only be accomplished using a richer quantitative model that captures household heterogeneity in a realistic way.

3 A model of the U.S. economy

To quantify how changes in the down-payment requirement affect households' consumption responses to income shocks, 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. Aggregate housing supply is also fully elastic in the long run, which implies that house prices in the benchmark analysis are unaffected by changes to the down-payment constraint. In Appendix D.2 we show that the main results do not 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. Overall, the model shares many features with the model in Karlman et al. (2021).

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 $N(0, \sigma_\alpha^2)$, and $g(j)$ is the age-dependent component of earnings, which captures the hump-shaped life-cycle profile. n_{ij} is an idiosyncratic random-walk component, which evolves according to a permanent income shock η_{ij}, distributed $N(0, \sigma_\eta^2)$. The household also draws an i.i.d. transitory shock ν_i, distributed $N(0, \sigma_\nu^2)$, which is uncorrelated with the permanent earnings shock. The log of the permanent earnings state z_{ij} in the model is given by the sum of the household-fixed component, the age-dependent component of earnings, and the random-walk component, i.e., $\log(z_{ij}) = \alpha_i + g(j) + n_{ij}$.

The social security benefits in retirement are given by a fixed proportion R of permanent earnings in the period before retirement, subject to a cap B^{max}. Further, the benefits are affected by transitory shocks, drawn from the same distribution as the transitory earnings shocks. Formally,

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

Assets and mortgages. Households enter the economy with different levels of initial 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.[5] 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.[6] 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

[5]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).

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

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 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.[7]

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.

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

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

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

from bequests is given by

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

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.

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

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

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,

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

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 $\tau^h p_h$.[8] 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 those in retirement. Overall, the government runs a surplus, which it spends on activities that do not affect the other agents in the economy.

The government collects property taxes from the rental firms, and taxes the households using three different taxes, as described in equation (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

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

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 tax 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 moments. As this class of models has a hard time matching the strong skewness in wealth that we see in the data, we choose to focus on the bottom 90 percent of the population in terms of net worth. We are interested in how households' consumption responses to income shocks are affected by changes to the down-payment requirement. The consumption responses of the very wealthy individuals presumably do not depend on this friction. Thus, restricting our attention to the bottom 90 percent of the wealth distribution 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.

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 log earnings equation (1), we use data from the Panel Study of Income Dynamics (PSID), survey years 1970 to 1992. In the estimation

Parameter	Description	Value
σ	Coefficient of relative risk aversion	2
τ^{ss}	Social security tax	0.153
τ^{h}	Property tax	0.01
r	Interest rate, bonds	0
r^{m}	Interest rate, mortgages	0.036
θ	Down-payment requirement	0.10
ψ	Payment-to-income requirement	0.177
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	60.4

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 2018 dollars.

of the age-dependent components of earnings $g(j)$, we follow Cocco et al. (2005).[9] 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

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

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 2013 into 21 equally-sized groups based on their reported earnings. We assume that a household has positive initial assets in the data whenever its asset holdings are larger than 1,000 in 2013 dollars. Within each earnings bin, we 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 1997 to 2013 on 3-month Treasury bill rates, deflated by the Consumer Price Index (CPI), the mean real rate is 0.06 percent.[10] The interest rate on risk-free bonds is therefore set to zero. The average real interest rate on long-term mortgages for the same period is equal to 3.6 percent. This is computed from the Federal Reserve's series of the contract rate on 30-year fixed-rate conventional home mortgage commitments, deflated by the CPI. Hence, we choose a yearly mortgage interest rate of 3.6 percent.

Between 1976 and 1992, the average down payment of first-time buyers in the U.S. ranged from 11 to 21 percent of the house value (U.S. Bureau of the Census, Statistical Abstract of the United States (GPO), 1987, 1988, and 1994). We use the lower bound of this interval, and set the down-payment requirement θ for new mortgages to 10 percent, as this helps us capture the upper tail of the LTV distribution. In Appendix D.6, we show that our main results remain if instead setting 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 roughly 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

[10]We use data from the Federal Reserve Bank of St Louis of the 3-month Treasury bill rate from the secondary market, seasonally adjusted, and the CPI data is the U.S. city average CPI for all urban consumers, all items.

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 2013 survey years. All parameters in Table 3 are jointly calibrated, taking the independently calibrated parameters in Table 1 as given.[11]

Parameter	Description	Value	Target moment	Data	Model
α	Consumption weight in utility	0.778	Median house value-to-earnings, age 23–64	2.26	2.26
β	Discount factor	0.953	Mean net worth, over mean earnings age 23–64	1.38	1.38
υ	Strength of bequest motive	4.20	Mean net worth age 75 over mean net worth age 50	1.64	1.64
Ψ	Utility bonus of owning	0.3	Mean own-to-rent size	1.80	1.94
δ^r	Depreciation rate, rentals	0.055	Homeownership rate, age 23–35	0.44	0.37
$\underline{h}$	Minimum owned house size	181	Homeownership rate, all ages	0.67	0.67
ς^r	Refinancing cost	2.524	Refinancing share, homeowners	0.08	0.08
λ	Level parameter, tax system	1.695	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 $\underline{h}$ and the fixed refinancing cost ς^r are in 1000's of 2018 dollars.

The consumption weight in the utility function α controls the share of expenditures that is allocated to consumption versus housing services. This weight is set to 0.778 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 mean net worth of households aged 75 over the mean net worth of households aged 50. The parameter value is calibrated to be 4.20.

[11] 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 A and B for a detailed description of the equilibrium definition and the solution method.

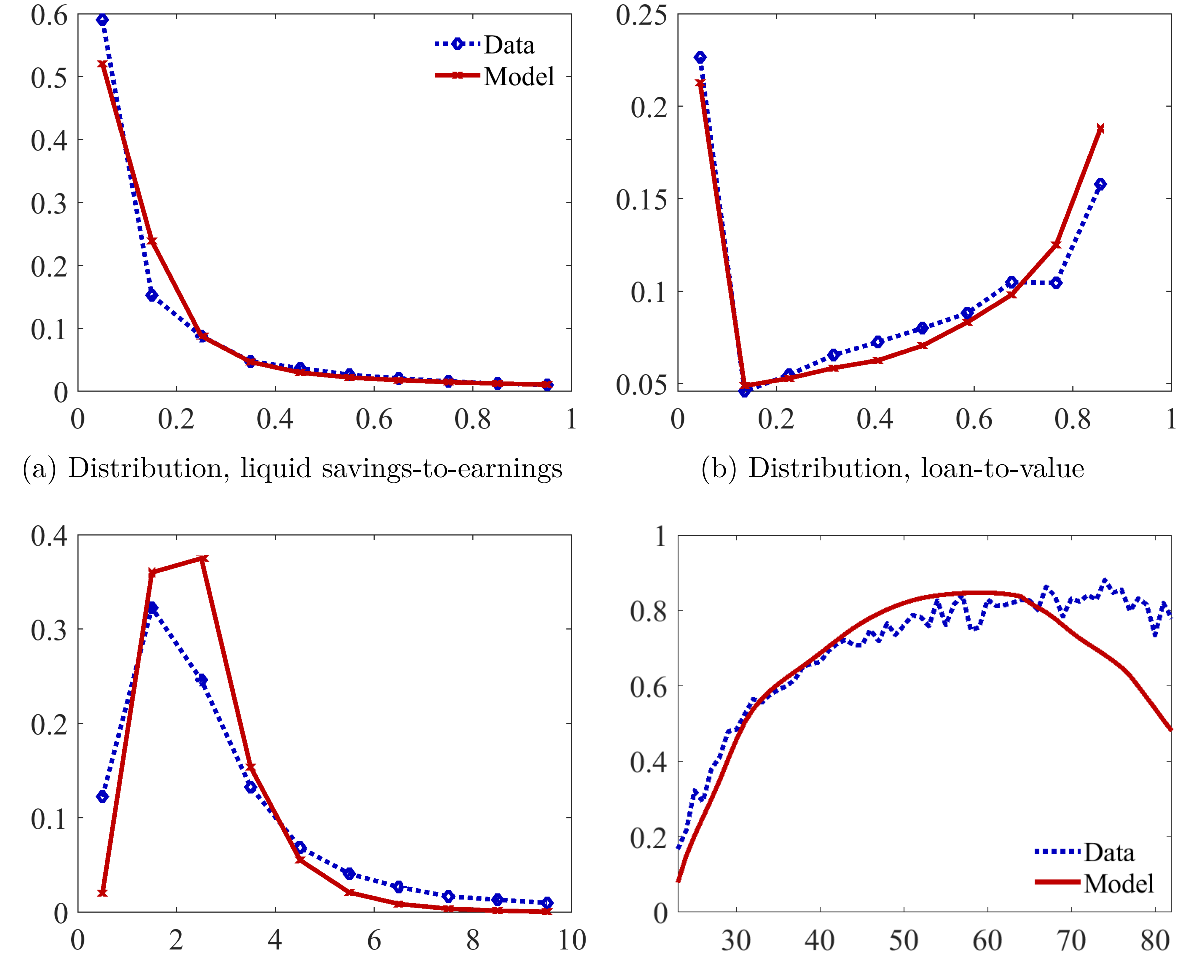
The decision to buy a house instead of renting housing services is affected by a number of factors in the model. Households generally prefer to own, however, frictions in the mortgage and housing markets stop some households from doing so. The positive net benefit of owning is due to the utility bonus 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 tax 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 young households, aged 23 to 35. The minimum house size available for purchase $\underline{h}$, which is strictly larger than the minimum house size available for rent, is set to match the overall homeownership rate in the data. To capture the liquidity of housing equity, we calibrate the fixed refinancing cost ς^r. With a cost of approximately 2 500 in 2018 dollars, we match the 8 percent refinancing rate among homeowners as stated in Chen et al. (2020).

The two parameters of the tax and transfer function $T(\tilde{y})$ are calibrated to match the level and the progressivity of earnings taxes in the U.S. The level parameter λ is set to 1.695, 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).

4.3 Data versus model: distributions

As the effect on MPCs of changes to the down-payment requirement depends on how constrained households are to begin with, it is important to compare key cross-sectional features of our model against the data. Figure 5 shows the distributions of liquid savings-to-earnings, LTVs, and house value-to earnings for the model and for the data from the SCF.[12] 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

[12] 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.



(a) Distribution, liquid savings-to-earnings

(b) Distribution, loan-to-value

(c) Distribution, house value-to-earnings

(d) Homeownership rate over life cycle

Figure 5: Comparison of data versus model

Note: The data is from the SCF, survey years 1989-2013. The model refers to the baseline economy. In Figure 5a and Figure 5c, only working-age households are included, and Figure 5b only displays homeowners.

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 5d, which the simple life-cycle model in Section 2.2 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. 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 unaffected 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.[13]

Although the papers study two different countries (Norway and the Netherlands) and 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 the households' consumption response to an income shock. As our goal is to study the link between the down-payment requirement and the MPC, we find it desirable to test whether our model can replicate this finding.

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 6 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.

[13] 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.

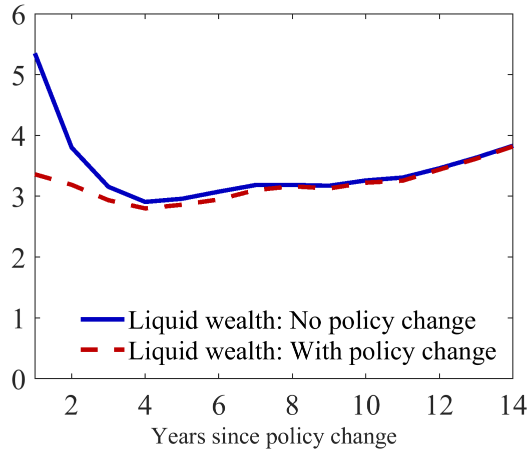


Figure 6: Mean bond holdings for affected house buyers
Note: The mean holdings of liquid bonds in each period after a house purchase among affected households, measured in 1000's of 2018 dollars. The affected households are defined as those who would have bought a house in the initial steady state with 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, we find that the overall mortgage issuance falls and that 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 from the model of the short-run implications of changing the down-payment requirement are qualitatively in line with results in the empirical literature. Reassured by these findings, we turn to the main focus of the paper: the long-run effects of changes to the down-payment constraint on households' consumption choices.

5 Quantitative results

Equipped with our model, we now turn to the quantitative analysis. We focus our attention on how permanent changes in the down-payment requirement affect individual and aggregate consumption responses to income shocks. Specifically, we examine how households' MPCs depend on the constraint. We then proceed by studying the implications of changes to the down-payment constraint for monetary and fiscal 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 fairly large shock of -4 000 dollars, to examine how households respond to economic distress, such as a job loss.[14] This is a significant shock, but still small enough to ensure that all households have positive cash-on-hand. In Appendix D.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.[15]

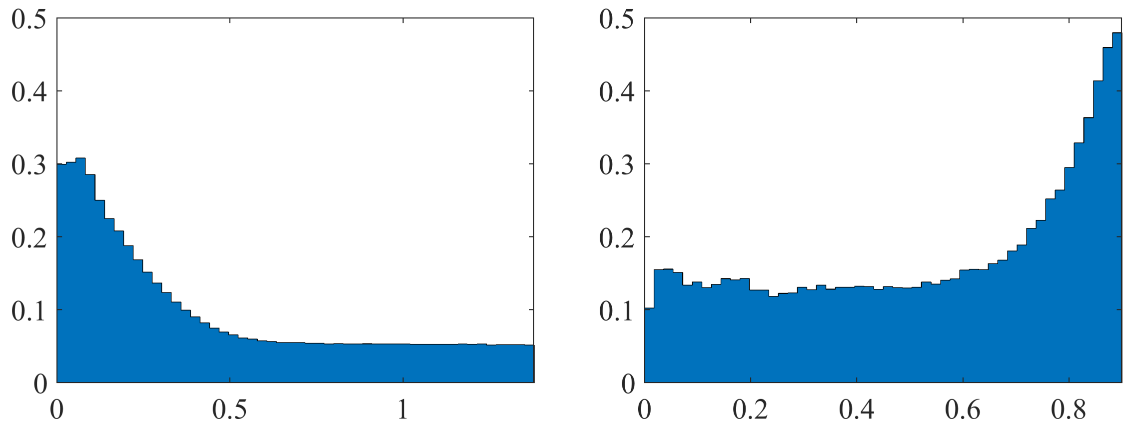
5.1 How does a stricter down-payment requirement affect consumption responses to income shocks?

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 7a displays the mean MPC across different ratios of liquid savings-to-earnings. As expected, 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 7b 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.

[14] Hereafter, dollar refers to 2018 dollar value.

[15] In Appendix D.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 house-price changes are relatively small.



(a) Liquid savings-to-earnings (b) Loan-to-value

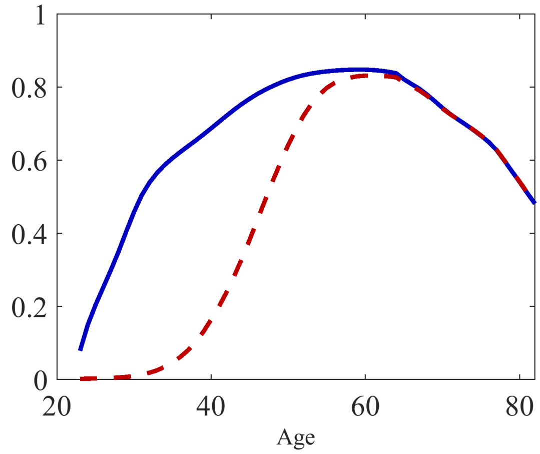
Figure 7: Mean MPC by liquid savings-to-earnings and LTV in the benchmark economy
Note: Liquid savings-to-earnings and loan-to-value are divided into 50 equally sized bins. Within each bin, the mean MPC is computed. To clearly depict the part of the distribution where households are somewhat constrained, 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 7b, 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 2.2, 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.

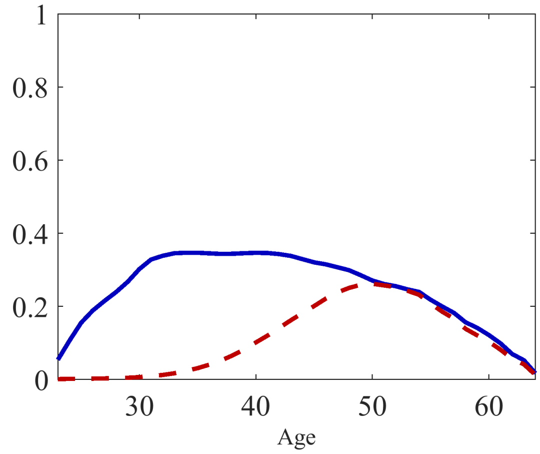
We begin our analysis of how households' choices depend on the down-payment requirement by comparing our baseline setting with a down-payment constraint of 10 percent to an economy where the requirement is 50 percent. This is a substantial increase in the constraint and it is mainly chosen to clearly illustrate the mechanisms of the model. In Figure 8, 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 2.2 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 are now older when buying their first home and the share of wealthy HtM households decreases among the relatively young.[16] In contrast, the share of HtM renters

[16] As illustrated in Figure 7, there is no single household variable that can summarize how constrained a household is. We therefore follow our definition in Section 2 and classify households as HtM according

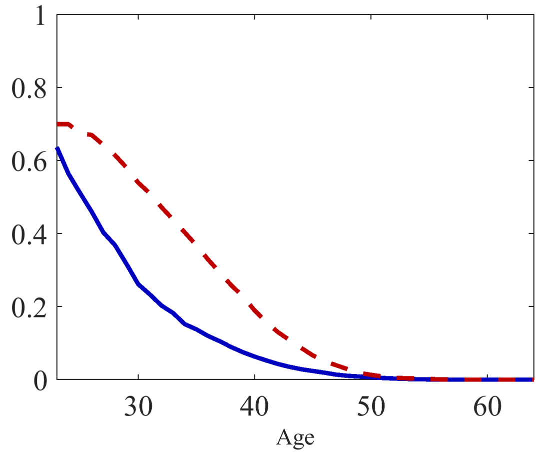
increases as the incentive to save is weaker for the young households. In addition to the extensive-margin response of delaying house purchases, we also find that households choose houses of smaller size/lower quality in response to the stricter requirement, as seen in Figure 12 in Appendix D.1. Finally, we note in Figure 8d 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.



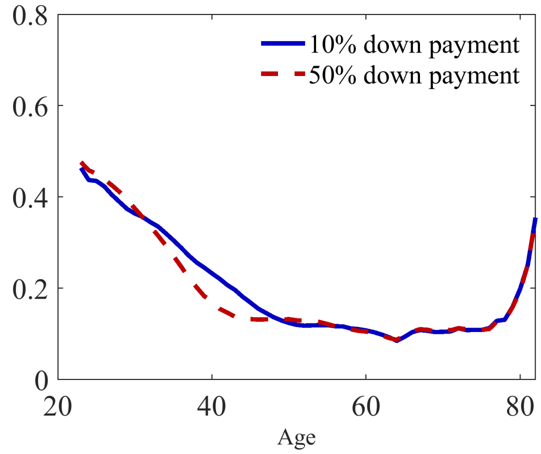
(a) Homeownership rate



(b) Share wealthy HtM households



(c) Share poor HtM households



(d) Mean MPC

Figure 8: The effects of an increased down-payment requirement over the life cycle

Figure 9 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

to their MPCs. In this section, we assume that a household is constrained if it has an MPC above 0.3. In Appendix D.4, we show that our results are similar for other threshold levels.

current level, when the down-payment requirement is 10 percent.

Overall, the mechanisms from the simple model survive when modeling the mortgage and housing markets in detail and after calibrating the model to the U.S. economy. A stricter down-payment requirement causes some households' MPC to decrease and others' to increase. Concretely, the share of wealthy hand-to-mouth households declines, whereas the share of poor hand-to-mouth households increases, as displayed in Figure 9. Hence, the overall effect on the mean MPC in the economy depends on which of the two effects dominates.

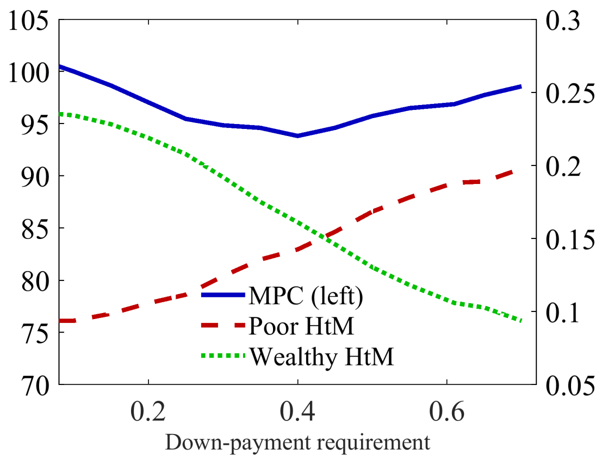


Figure 9: Mean MPC (percent of baseline) and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements

5.2 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 in 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.[17] We see that the direct cash-flow effects of monetary policy are highly

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

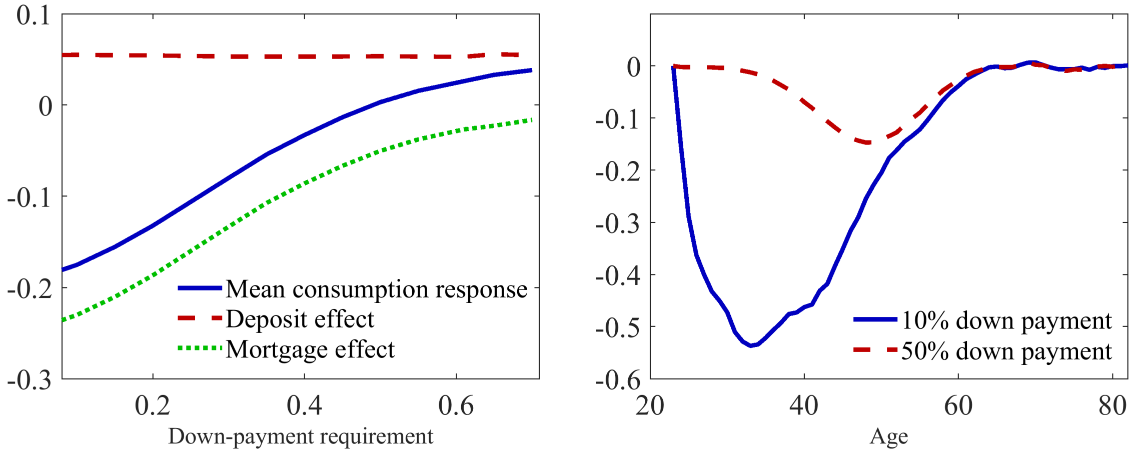
dependent on the down-payment constraint. At the current level of the requirement, consumption contracts by approximately 0.18 percent in response to the interest-rate increase. However, with a down-payment constraint of 30 percent the consumption response is approximately halved. Moreover, at very strict 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 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 reduces the effectiveness of monetary policy. The reduced effectiveness is largely explained by a dampened mortgage cash-flow channel. Interestingly, if considering a setting where the down-payment constraint is larger than 40 percent, we find that the mean MPC in the economy would decrease if the constraint is relaxed, at the same time as monetary policy would become more effective.

5.3 Implications for fiscal policy: cash-transfer schemes

Cash-transfer schemes have been used by governments in many countries. In the U.S., for example, significant cash transfers were an important part of the stabilization policy in 2001, 2007–2009, and during the latest pandemic crisis. Our results in the previous sections suggest that there is considerable heterogeneity in how households' MPC adjusts to changes in the down-payment requirement. Thus, the way in which cash transfers should be distributed is likely to depend on the level of the constraint.



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

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

To better understand how the effectiveness of cash-transfer schemes depends on the down-payment requirement, Figure 11 shows how the mean MPC changes with the constraint for three different income groups.[18] 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 high enough 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 purposes. Hence, while many of the middle-income households become renters with high

[18]Low income corresponds to households at the bottom 30 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.

MPCs, high-income households tend to become renters with low MPCs. As a result, the mean MPC is falling throughout for this group.

Our analysis of MPCs across income groups has two messages that are of policy relevance. First, it is always the most effective to target low-income households for fiscal transfers, as seen by the consistently higher mean MPC of this group. Second, with a stricter down-payment constraint, it becomes increasingly important to direct cash transfers towards low-income households.

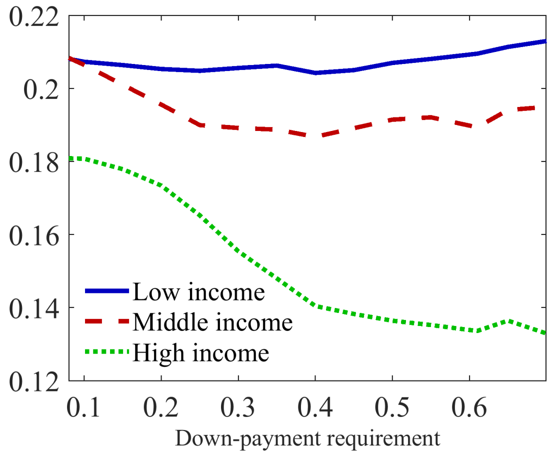


Figure 11: Mean MPC for different income groups, across various down-payment requirements

6 Conclusion

Since the Great Recession, policymakers in many countries have implemented stricter mortgage lending standards. In particular, LTV constraints 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. Although the effects of stricter traditional borrowing constraints are well understood, we know much less about the implications of tougher down-payment requirements. In this paper, we investigate how different households' savings and consumption choices are affected by a stricter down-payment constraint, and the implications for macroeconomic aggregates and policy.

We show that some households' MPC decreases whereas others' increases as a result of a stricter down-payment regulation. A stricter down-payment requirement causes the share of wealthy HtM households to decrease, but it also leads to a larger number of poor HtM households with high MPC. The last effect depends on a limited availability of non-secured borrowing. Thus, there is an interesting interaction between a down-payment requirement and a traditional borrowing constraint. We also show that the mean MPC in the economy is U-shaped in the down-payment requirement. Both of these findings highlight that a down-payment constraint leads to fundamentally different outcomes than a traditional borrowing limit, which has a weakly positive relationship with MPCs.

In a quantitative analysis of the U.S. economy, we find that the minimum mean MPC is achieved when the down-payment constraint is approximately 40 percent. At this level, the mean MPC is roughly 5 percent lower than at the current level of the constraint. We then evaluate the implications of a stricter down-payment requirement for monetary and fiscal 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.

References

Aastveit, K. A., R. Juelsrud, and E. Getz Wold (2020, June). Mortgage regulation and financial vulnerability at the household level. Working paper, Norges Bank Research.

Acharya, V. V., K. Bergant, M. Crosignani, T. Eisert, and F. J. McCann (2020, May). The anatomy of the transmission of macroprudential policies. Working Paper 27292, National Bureau of Economic Research.

Agarwal, S. and W. Qian (2014). Consumption and debt response to unanticipated income shocks: Evidence from a natural experiment in Singapore. *American Economic Review 104*(12), 4205–4230.

Andersen, A., C. Duus, and T. L. Jensen (2017). Household debt and spending during the financial crisis: Evidence from Danish micro data. *European Economic Review 92*, 47–73.

Angelini, P., S. Nicoletti-Altimari, and I. Visco (2012, November). Macroprudential, microprudential and monetary policies: conflicts, complementarities and trade-offs. Occasional Paper No. 140, SSRN.

Baker, S. (2018). Debt and the response to household income shocks: Validation and application of linked financial account data. *Journal of Political Economy 126*(4), 1504–1557.

Bell, F. C. and M. L. Miller (2005, August). Life tables for the United States Social Security Area 1900-2100. Actuarial study No. 120, Social Security Administration.

Bewley, T. (1977, December). The permanent income hypothesis: A theoretical formulation. *Journal of Economic Theory 16*(2), 252–292.

Boar, C., D. Gorea, and V. Midrigan (2021, 09). Liquidity Constraints in the U.S. Housing Market. *The Review of Economic Studies 89*(3), 1120–1154.

Bunn, P. and M. Rostom (2015, May). Household debt and spending in the United Kingdom. Working paper No. 554, Bank of England Staff Working Paper.

Calza, A., T. Monacelli, and L. Stracca (2013, 01). Housing finance and monetary policy. *Journal of the European Economic Association 11*, 101–122.

Carroll, C. D. and A. A. Samwick (1997). The nature of precautionary wealth. *Journal of Monetary Economics 40*(1), 41–71.

Chen, H., M. Michaux, and N. Roussanov (2020). Houses as ATMs: mortgage refinancing and macroeconomic uncertainty. *The Journal of Finance 75*(1), 323–375.

Cho, S.-W. and J. Francis (2011). Tax treatment of owner occupied housing and wealth inequality. *Journal of Macroeconomics 33*, 42–60.

Cloyne, J., C. Ferreira, and P. Surico (2019, 01). Monetary policy when households have debt: New evidence on the transmission mechanism. *The Review of Economic Studies*, 41–28. rdy074.

Cocco, J. F., F. J. Gomes, and P. J. Maenhout (2005). Consumption and portfolio choice over the life cycle. *Review of Financial Studies 18*(2), 491–533.

Di Maggio, M., A. Kermani, B. J. Keys, T. Piskorski, R. Ramcharan, A. Seru, and V. Yao (2017, November). Interest rate pass-through: Mortgage rates, household consumption, and voluntary deleveraging. *American Economic Review 107*(11), 3550–88.

Díaz, A. and M. J. Luengo-Prado (2008). On the user cost and homeownership. *Review of Economic Dynamics 11*(3), 584–613.

Druedahl, J. and T. H. Jørgensen (2017). A general endogenous grid method for multi-dimensional models with non-convexities and constraints. *Journal of Economic Dynamics and Control 74*, 87–107.

Dynan, K., A. Mian, and K. M. Pence (2012). Is a household debt overhang holding back consumption? [with comments and discussion]. *Brookings Papers on Economic Activity*, 299–362.

Fagereng, A., M. Holm, and G. Natvik (2021). MPC heterogeneity and household balance sheets. *American Economic Journal: Macroeconomics 13*(4), 1–54.

Ferrero, A., R. Harrison, and B. Nelson (2018, December). House price dynamics, optimal LTV limits and the liquidity trap. Discussion Paper No. DP13400, CEPR.

Flodén, M., M. Kilström, J. Sigurdsson, and R. Vestman (2020, 12). Household Debt and Monetary Policy: Revealing the Cash-Flow Channel. *The Economic Journal 131*(636), 1742–1771.

Floetotto, M., M. Kirker, and J. Stroebel (2016). Government intervention in the housing market: who wins, who loses? *Journal of Monetary Economics 80*, 106–123.

Gervais, M. (2002). Housing taxation and capital accumulation. *Journal of Monetary Economics 49*(7), 1461–1489.

Greenwald, D. (2018). The mortgage credit channel of macroeconomic transmission. *Working Paper*.

Gruber, J. W. and R. F. Martin (2003). Precautionary savings and the wealth distribution with illiquid durables. *International Finance Discussion Papers 773*.

Guren, A., A. Krishnamurthy, and T. McQuade (2021). Mortgage design in an equilibrium model of the housing market. *The Journal of Finance 76*(1), 113–168.

Harding, J. P., S. S. Rosenthal, and C. Sirmans (2007). Depreciation of housing capital, maintenance, and house price inflation: estimates from a repeat sales model. *Journal of Urban Economics 61*(2), 193–217.

Harris, E. (2005, November). Effective marginal tax rates on labor income. A CBO paper, Congressional Budget Office.

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

Holm, M. B., P. Paul, and A. Tischbirek (2021). The transmission of monetary policy under the microscope. *Journal of Political Economy 129*(10), 2861–2904.

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

Kaplan, G. and G. Violante (2014). A model of the consumption response to fiscal stimulus payments. *Econometrica 82*(4), 1199–1239.

Kaplan, G., G. Violante, and J. Weidner (2014). The wealthy hand-to-mouth. *Brookings Papers on Economic Activity 45*(1), 77–153.

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

Kinnerud, K. (2022). The effects of monetary policy through housing and mortgage choices on aggregate demand. *Working Paper*.

Kovacs, A., M. Rostom, and P. Bunn (2018). Consumption response to aggregate shocks and the role of leverage. Discussion Paper 1820, Centre for Macroeconomics.

Krusell, P. and A. A. Smith, Jr. (1998). Income and wealth heterogeneity in the macroeconomy. *Journal of Political Economy 106*(5), 867–896.

Lim, C. H., A. Costa, F. Columba, P. Kongsamut, A. Otani, M. Saiyid, T. Wezel, and X. Wu (2011, October). Macroprudential policy: what instruments and how to use them? Lessons from country experiences. IMF Working Paper No. 11/238.

Mian, A., K. Rao, and A. Sufi (2013). Household balance sheets, consumpton, and the economic slump. *The Quarterly Journal of Economics 128*(4), 1687–1726.

Mian, A. and A. Sufi (2014). *House of debt: how they (and you) caused the Great Recession and how we can prevent it from happening again.* University of Chicago Press, Chicago.

Parker, J., N. Souleles, D. Johnson, and R. McClelland (2013). Consumer spending and the economic stimulus payments of 2008. *American Economic Review 103*(6), 2530–2553.

Peydro, J.-L., F. Rodriguez-Tous, J. Tripathy, and A. Uluc (2020, May). Macroprudential policy, mortgage cycles and distributional effects: Evidence from the UK. Working paper No. 866, Bank of England Staff Working Paper.

Piazzesi, M. and M. Schneider (2016). Housing and macroeconomics. *Handbook of Macroeconomics 2*, 1547–1640.

Scheinkman, J. A. and L. Weiss (1986). Borrowing constraints and aggregate economic activity. *Econometrica 54*(1), 23–45.

Sommer, K. and P. Sullivan (2018). Implications of US tax policy for house prices, rents, and homeownership. *American Economic Review 108*(2), 241–74.

Van Bekkum, S., M. Gabarro, R. Irani, and J.-L. Peydro (2019). Take it to the limit? The effects of household leverage caps. *Working Paper*.

Verner, E. and G. Gyöngyösi (2020, September). Household debt revaluation and the real economy: Evidence from a foreign currency debt crisis. *American Economic Review 110*(9), 2667–2702.

Appendices

A Definitions of stationary equilibrium

Households are heterogeneous with respect to age $j \in \mathcal{J} \equiv \{1, 2, ..., J\}$, permanent earnings $z \in \mathcal{Z} \equiv \mathbb{R}_{++}$, mortgage $m \in \mathcal{M} \equiv \mathbb{R}_{+}$, owner-occupied housing $h \in \mathcal{H} \equiv \{0, \underline{h}, ..., \bar{h} = \bar{s}\}$, 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, exogeneous 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[19]

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

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

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

[19]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.

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

Stationary equilibrium, endogeneous 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.

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

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

B 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^2EGM by Druedahl and Jørgensen (2017) to solve for the value and policy functions. The number of grid points for permanent earnings N_Z, cash-on-hand N_X, housing sizes N_H, bonds-over-earnings N_B, and loan-to-value N_{LTV}, are 9, 140, 30, 25, and 41, respectively. The grid points are denser at lower levels of cash-on-hand and bonds-over-earnings. Further, we simulate 300 000 households for $J = 60$ periods.

C Labor income process

C.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).

C.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

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

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

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

D Additional results

D.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 50 percent. Most attention should be paid to ages 40 to 55, since there are almost no homeowners younger than 40 when the required down payment is 50 percent, as illustrated in Figure 8. For almost all ages, households own larger homes when lending standards 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.

D.2 Endogenous house prices

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 this section, we instead make the opposite assumption. 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

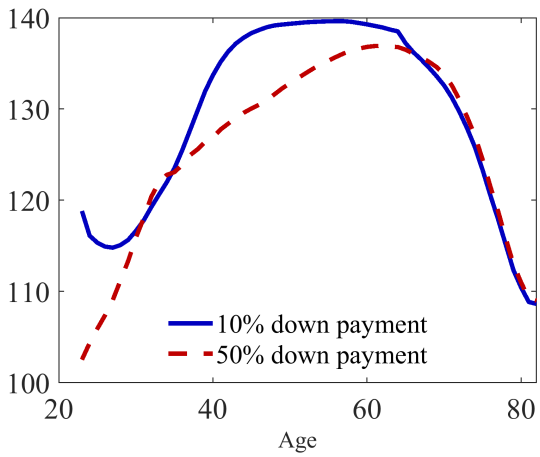


Figure 12: Mean house size (quality) conditional on owning in both equilibria, over the life cycle

elastic housing supply.

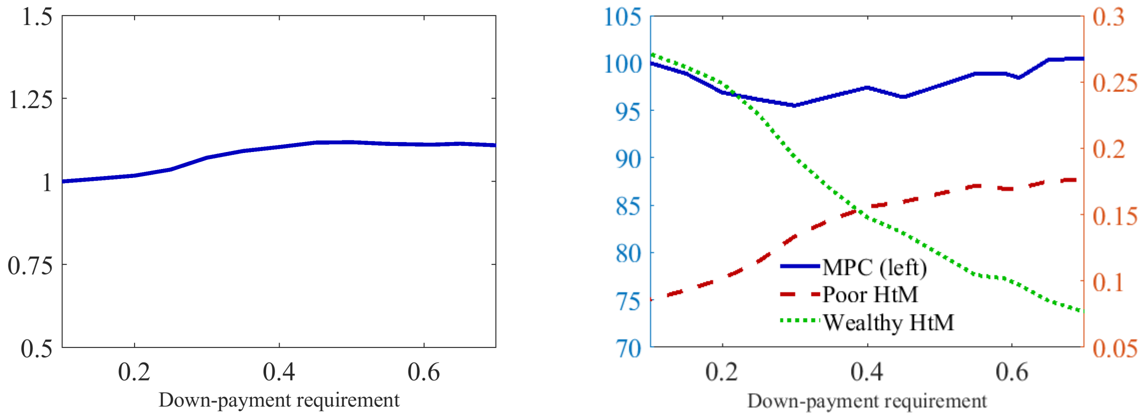
Figure 13a shows the house price as a function of the down-payment requirement. As evident, the connection between the down-payment constraint and house prices is weak. This finding is not new, and we refer the reader to Kaplan et al. (2020) for an in-detail discussion. Essentially, the primary consequence of stricter mortgage 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 in the long run.

Figure 13b 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 9. Given the weak effect on prices, the absolute size of the down payment required is roughly the same whether prices are allowed to change 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.

D.3 Varying the shock size

In the core analysis of this paper we focus on the consumption response to a negative income shock. Moreover, the size of the shock is somewhat arbitrarily, and is of quite significant magnitude. 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 highest



(a) House prices

(b) MPC and the shares of HtM households

Figure 13: House prices, 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

line, corresponding to the negative shock of 4 000 dollars, is the same as in Figure 9. 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, which is used in the main analysis, the average MPC is just above 0.2 when the down-payment constraint is 0.10. When we instead consider a positive shock of the same magnitude, the mean MPC falls around 10 percent to 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.

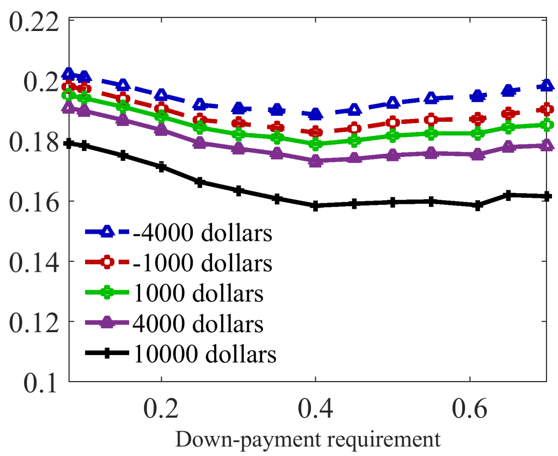
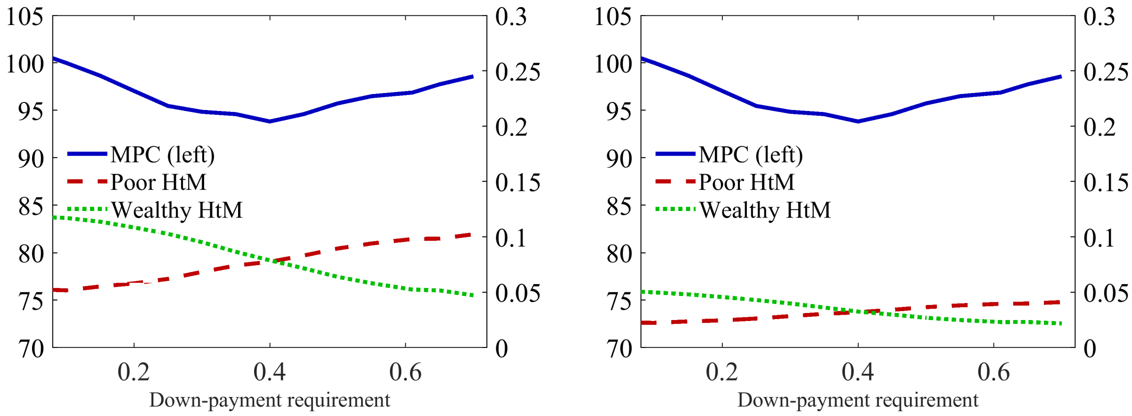


Figure 14: Mean MPC across various down-payment requirements for positive and negative shocks of different sizes

D.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 clearly 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

D.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

$$\sigma_\eta^2 = \frac{\sigma_y^2(J_{ret}) - \sigma_y^2(1)}{J_{ret} - 1} \tag{16}$$

$$\sigma_\alpha^2 = \sigma_y^2(1) - \sigma_\eta^2 - \sigma_\upsilon^2. \tag{17}$$

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. Estimated with PSID data, years 1970 to 1992.

With a different income process, the model needs to be recalibrated to match the targeted moments. The resulting calibration is shown in Table 5. Compared to the baseline calibration, the discount factor β, the bequest weight υ, the minimum owned house size $\underline{\mathrm{h}}$, and the refinancing cost ς^r, change more than marginally. Since the lower transitory income risk reduces households' precautionary savings, the discount factor and the strength of the bequest motive need to adjust to match the target moments related to net worth. Moreover, the minimum available house size to own needs to be lowered in order to better match the homeownership rate in the data. The lower transitory income risk also makes households less prone to refinance their mortgage. Hence, in the new calibration the refinancing cost is reduced to match the observed refinancing share.

Figure 16 illustrates the relationship between the required down payment and the mean MPC and the shares of HtM households. The results are qualitatively, and to a large extent quantitatively, similar to the baseline model. While less transitory risk does mitigate the precautionary savings motive, the effect on savings is partly offset by the recalibration of the model that is required to match the moments in the data. The mean MPC is again U-shaped, but the minimum is achieved at a somewhat smaller

Parameter	Description	Value	Target moment	Data	Model
α	Consumption weight in utility	0.778	Median house value-to-earnings, age 23–64	2.26	2.21
β	Discount factor	0.959	Mean net worth, over mean earnings age 23–64	1.38	1.37
υ	Strength of bequest motive	3	Mean net worth age 75 over mean net worth age 50	1.64	1.61
Ψ	Utility bonus of owning	0.28	Mean own-to-rent size	1.80	1.94
δ^r	Depreciation rate, rentals	0.055	Homeownership rate, age 23–35	0.44	0.44
$\underline{h}$	Minimum owned house size	143	Homeownership rate, all ages	0.67	0.74
ς^r	Refinancing cost	1.62	Refinancing share, homeowners	0.08	0.08
λ	Level parameter, tax system	1.695	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 2018 dollars.

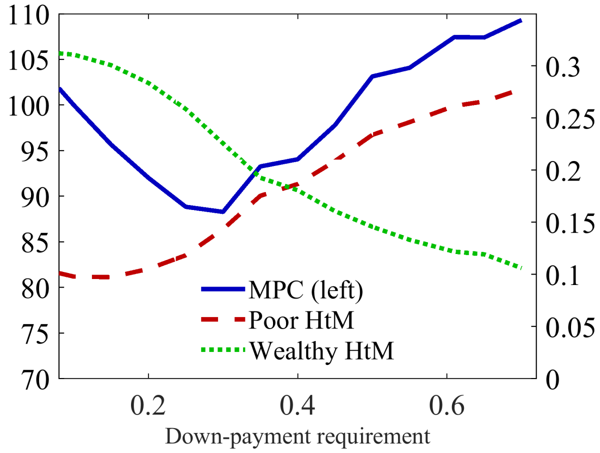


Figure 16: Mean MPC (percent of baseline) and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, in a setting with less transitory income risk

down-payment constraint than in the baseline calibration, and the reduction in the mean MPC is almost 10 percent, as opposed to 5 percent in the baseline.

D.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. Relative to the baseline calibration, the changes are marginal except for the discount factor β, the depreciation rate of rental housing δ_r, and the minimum owned house size $\underline{h}$. The latter two need to be adjusted to make it easier and more attractive to buy a home, in order to match homeownership moments in the data, since the higher down-payment requirement makes it more difficult to buy. In addition, since households buy with more equity, the discount factor needs to be adjusted to make sure the wealth-to-earnings ratio is matched to the data.

Parameter	Description	Value	Target moment	Data	Model
α	Consumption weight in utility	0.767	Median house value-to-earnings, age 23–64	2.26	2.24
β	Discount factor	0.946	Mean net worth, over mean earnings age 23–64	1.38	1.37
υ	Strength of bequest motive	4.2	Mean net worth age 75 over mean net worth age 50	1.64	1.59
Ψ	Utility bonus of owning	0.3	Mean own-to-rent size	1.80	1.94
δ^r	Depreciation rate, rentals	0.06	Homeownership rate, age 23–35	0.44	0.41
$\underline{h}$	Minimum owned house size	161	Homeownership rate, all ages	0.67	0.73
ς^r	Refinancing cost	2.524	Refinancing share, homeowners	0.08	0.08
λ	Level parameter, tax system	1.695	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 $\underline{h}$ and the fixed refinancing cost ς^r are in 1000's of 2018 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 larger than the 5 percent reduction in the main analysis.

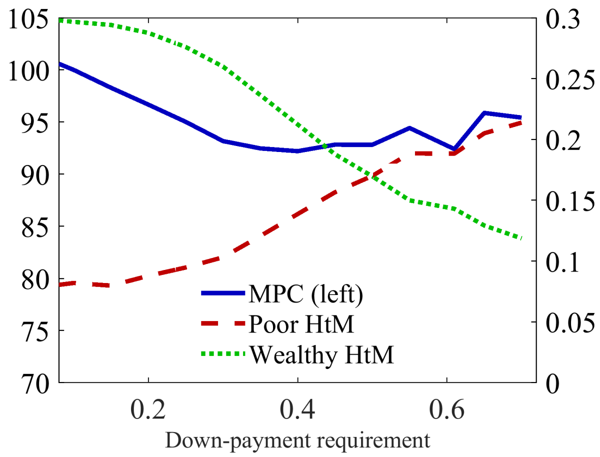


Figure 17: Mean MPC (percent of baseline) and the shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, setting $\theta = 0.2$ in the baseline calibration