Down-payment requirements: Implications for portfolio choice and consumption

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Abstract

This paper studies how down-payment requirements for house purchases affect households' saving and housing decisions, and the implications for macroeconomic policy. Using a quantitative model, we find that households not only postpone homeownership when the down-payment constraint is higher, but they also delay when they start saving for the house. We show analytically that this result holds under standard assumptions for households' earnings and preferences. The changes to saving and portfolio choices affect the distribution of liquidity-constrained households, which in turn impacts aggregate responses to policy. Specifically, the cash-flow channel of monetary policy is reduced, and it becomes increasingly important to direct fiscal transfers at low-income households to achieve the largest consumption response. We also find that a stricter down-payment requirement is associated with substantial welfare costs, especially for high-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

How does the consumption and saving behavior of households depend on borrowing constraints? This question has attracted considerable attention in economics.[1] In this paper, we revisit the topic in light of two recent developments.

First, a growing empirical and theoretical literature underscores the importance of households' savings in assets of varying liquidity for understanding the distribution of marginal propensities to consume (MPCs) and the effects of macroeconomic policies. A key result in this literature is that many relatively wealthy households primarily hold illiquid assets, which makes them liquidity constrained with high MPCs. The fact that many wealthy households have large consumption responses to income shocks has implications for both fiscal and monetary policy.[2] Given the importance of illiquid assets, it is crucial to understand how constraints on secured borrowing, where the illiquid asset is used as collateral, affect household behavior.

Second, there is an increase in the number of countries that have implemented down-payment requirements for house purchases. Figure 1 shows that the fraction of advanced economies with such a requirement in place has increased from merely 6 percent in 1990 to over 60 percent in 2020 (Alam et al., 2019). Moreover, the average down-payment requirement, among the countries that have implemented a constraint, has increased from approximately 3 percent to over 20 percent. Even though housing is the predominant illiquid asset for most households, our current understanding of how changes to the down-payment constraint influence households' consumption and saving behavior is limited. Specifically, a number of empirical papers have studied short-run effects of a change in the constraint, but little is known about long-run and aggregate implications (see, e.g., Aastveit et al. (2020), Acharya et al. (2022), and Van Bekkum et al. (2024)).

This paper contributes by providing a theoretical framework that rationalizes findings in the empirical literature on effects of stricter down-payment requirements. This framework is then used to make predictions of long-run implications of changes to the constraint and how these effects impact fiscal and monetary policy. Our three main results are as follows. First, we show that a stricter down-payment requirement significantly alters households' saving and portfolio choices over the life cycle. In particular, households find it optimal to delay homeownership *and* postpone when they start saving for the house. Hence, even if households need more savings to purchase a house, a stricter down-payment constraint actually makes households save less when they are young. We show analytically that this

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

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

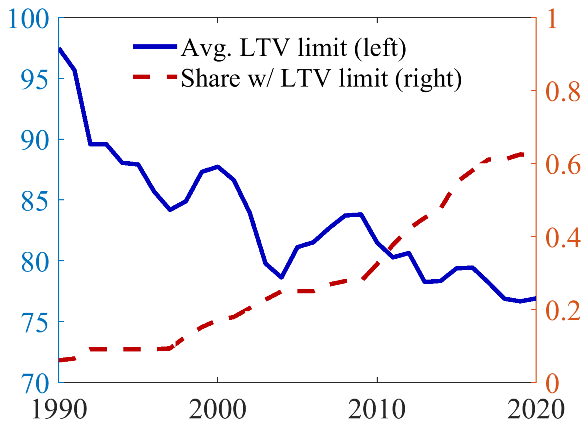


Figure 1: Prevalence of loan-to-value limits among advanced economies
Note: A loan-to-value (LTV) requirement is equivalent to one minus the down-payment constraint. For example, an LTV requirement of 80 percent is equivalent to a down-payment requirement of 20 percent. The data is for all advanced economies.
Source: The IMF's integrated Macroprudential Policy (iMaPP) Database, originally constructed by Alam et al. (2019).

mechanism holds under standard assumptions for households' earnings and preferences. Second, we show that the change in saving behavior significantly alters which households are liquidity constrained. As young renters decrease their savings, the share of poor hand-to-mouth (HtM) households with high MPCs increases. On the other hand, the delayed house purchase reduces the number of liquidity-constrained homeowners with high MPCs, i.e., the share of wealthy HtM households declines. As a result, we find that the mean MPC in the economy is relatively stable, despite the notable changes in the MPC distribution. The mean MPC is at most lowered by approximately 5 percent, which occurs if the required down payment is increased to 40 percent. Third, the heterogeneous effects on households' saving and portfolio choices have important implications for policy and welfare. Specifically, the cash-flow channel of monetary policy is reduced and it becomes increasingly important to direct fiscal transfers to low-income households, when the down-payment constraint is stricter. In terms of welfare, a larger down-payment requirement is associated with significant costs, especially for high-income households.

We begin our analysis by constructing a stylized life-cycle model to highlight qualitatively how the down-payment constraint shapes households' saving behavior. We then proceed by building a heterogeneous-household incomplete-markets model to quantitatively assess the implications of a stricter constraint. The stylized model is a standard consumption-saving problem in continuous time, where households face an upward-sloping earnings profile. This model is appended with a traditional borrowing constraint as well as a down-payment requirement. The former restricts young households with relatively low earnings from perfectly smoothing consumption. The latter specifies the savings required to become a homeowner. Owning is preferred to renting, but the down-payment requirement restricts access to ownership and creates a trade-off. On the one hand, households want to save to become homeowners. On the other hand, saving for the down payment is costly as households have to forgo consumption in the periods that they save. We show that the solution to the household problem is fully characterized by the optimal time to start saving, which is when the marginal benefit of postponing saving equals the marginal cost.

Using this model, we show that an increased down-payment requirement leads to a delay in when households start to save. The intuition is as follows. A stricter constraint increases the cost of accumulating the required savings, since saving a larger amount implies larger deviations from consumption smoothing. Importantly, since the utility function is concave, the increase in the cost of saving is larger for younger households, as they have lower income and consumption. It is therefore optimal for them to delay saving until later in life when their income is higher. The delay in the time of starting to save also implies a postponement of ownership. We show that these results hold for any reasonable shape of the life-cycle earnings profile.

The simple model highlights how households' saving behavior depends on the down-payment requirement. In order to quantitatively evaluate what this implies for different macroeconomic outcomes we proceed by constructing a model of the U.S. economy.[3] In particular, we want to assess how households' MPCs are affected by the down-payment constraint, and the implications for monetary and fiscal policy.

Our quantitative model is a rich life-cycle model with heterogeneous households, where mortgage and housing markets are modeled in detail. Markets are incomplete as idiosyncratic earnings risk is not fully insurable. Households derive utility from non-durable consumption goods and housing services, where housing services can be obtained by either renting or owning houses of different sizes. A household can save in liquid, risk-free bonds, and also in illiquid housing equity. There are transaction costs associated with both buying and selling a house, and there are down-payment and payment-to-income (PTI) constraints that limit the size of new mortgages. Finally, it is costly to use cash-out refinancing to access housing equity.

The model is calibrated to the U.S. economy and matches important features of the data, including the distributions of liquid savings-to-earnings, debt, housing wealth-to-

[3]We choose the U.S. as our laboratory, although there is currently no hard down-payment constraint in place. We do so since frictions in the U.S. mortgage market have received considerable attention in the literature, see, e.g., Boar et al. (2021), Chambers et al. (2009), Garriga and Hedlund (2020) and Greenwald (2018), and there is substantial bunching at different LTV thresholds in the U.S. data, indicating that there are de facto constraints in place. We also verify that the results are similar if we instead consider Norway, which has a formal down-payment requirement, and if we incorporate that the U.S. currently has a soft LTV constraint, see Appendix F.6.

earnings, as well as the life-cycle profile of homeownership. The model also produces a rich distribution of MPCs across households. Portfolio choices, in terms of leverage, housing, and liquid bond holdings, play an important role in determining households' MPC. In line with the data, a significant portion of renters hold 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. (2024)).

Consistent with the simple life-cycle model, our quantitative model shows that households both postpone buying a house and delay when they start saving for the down payment, when the constraint is stricter. Importantly, this results in a reduction of the share of wealthy HtM households, and an increase in the share of poor HtM. The overall effect on mean MPC is relatively small and depends on which of the two effects dominate, which in turn depends on how strict the constraint is to begin with. In fact, we find that the mean MPC is U-shaped in the down-payment requirement and it 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. Thus, for most policy-relevant increases of the constraint, the mean MPC decreases, but to a relatively small extent.

While the effect on the average MPC is modest, we find that a stricter down-payment requirement has important implications for welfare and macroeconomic policy. Since households adjust their saving and portfolio choices in response to a tighter constraint, the welfare costs of the households are considerable.[4] High-earning households are particularly affected, since they tend to buy a house when they are fairly young and when their income profile is steep. As a result, additional savings are relatively costly in utility terms. We also find that a stricter down-payment constraint dampens the mortgage cash-flow channel of monetary policy, since it decreases the mortgage balance among the liquidity-constrained homeowners, making monetary policy less potent. In terms of fiscal policy, we see that although transfers to low-income households are always the most effective, a stricter down-payment requirement makes it relatively more important to target these households.

Previous literature. This paper relates to the literature on down-payment and LTV constraints, and how these affect households' saving and consumption behavior. A number of papers use theoretical models to explain how down-payment requirements affect household behavior. Artle and Varaiya (1978) consider how the homeownership choice affects consumption over the life cycle, when there is a down-payment constraint

[4]We assess how costly a constraint is to households. A full-fledged welfare analysis is beyond the scope of this paper, as it would require a detailed modeling of factors related to financial stability, which include modeling the banking sector, aggregate risk, and negative externalities of default.

in place. Slemrod (1982) studies how a down-payment requirement impacts effects of tax policies. Stein (1995) and Ortalo-Magne and Rady (2006) investigate the role of down-payment requirements in explaining, e.g., house price and transaction volume variability. We complement this line of work by showing how down-payment constraints impact consumption, saving, and portfolio choices over the life cycle, and highlight the implications for macroeconomic policy. Chambers et al. (2009) show that a relaxation of down-payment constraints was important for the increase in the homeownership rate between 1994 and 2005. In line with this result, we find that stricter down-payment requirements make households buy their first home later, and we then investigate the implications of this for households' MPCs and, in turn, aggregate effects of monetary and fiscal policy.

A richer and more recent literature conducts empirical investigations of down-payment constraints. Engelhardt (1996) shows that most households increase consumption significantly at the time they purchase their first home, indicating that they are constrained by the requirement. Fuster and Zafar (2016) provide survey evidence that households' likelihood of buying a home reacts strongly to the size of the required down payment. 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. (2022) find that stricter LTV constraints in Ireland lead to a significant reallocation of mortgage debt and housing. Gupta et al. (2023) show that the down-payment constraints implicit in the U.S. mortgage market have become stricter, and find that this has contributed to spatial misallocation and wealth inequality. Most closely related to our work are Aastveit et al. (2020) and Van Bekkum et al. (2024). They 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 less liquid savings, making the effect on financial vulnerability uncertain. Aastveit et al. (2020) and Van Bekkum et al. (2024) offer valuable empirical evidence of how LTV requirements affect marginal home buyers in the short 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. As such, our model provides a rationale for their reduced-form estimates. Our paper further 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 saving behavior of households that are not directly affected by the constraint, i.e., young renters.

A limitation of our analysis is that we consider the changes in down-payment constraints to be exogenous: one can always argue that any change in regulations, taxes, or constraints is endogenous. However, as indicated in Figure 1, regulatory LTV constraints have historically been implemented in many different settings, during different economic circumstances, in different countries, across time, and at different levels. Thus, it appears possible that at least some of these changes are exogenous. It is therefore of independent interest to examine exogenous changes, which also provides valuable information to policy makers. In addition, a benefit of our approach is that by considering exogenous changes to the down-payment constraint, we can control for the environment and are not restricted to any particular episode or past setting. This type of analysis follows a tradition in the quantitative macroeconomic literature where seemingly ad hoc changes to policies and constraints are considered. Similar strategies are used in, e.g., Corbae and Quintin (2015); Favilukis et al. (2017); Floetotto et al. (2016); Garriga and Hedlund (2020); Gete and Zecchetto (2017); Greenwald (2018); Greenwald et al. (2021); Kaplan et al. (2020); Sommer and Sullivan (2018). In all these cases, changes in the policy variables in the data can arguably both contain endogenous and exogenous parts.

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 households' saving choices. In Section 3, we proceed by constructing a model of the U.S. economy. The model is then calibrated in Section 4. Here, we also compare the performance of the model to the data and validate the model against the empirical findings of the short-run effects of stricter down-payment requirements. Section 5 presents the main quantitative results and Section 6 concludes the paper.

2 Down-payment requirements in a simple framework

In this section, we study a standard consumption-saving problem that is extended to include a down-payment requirement. We use this simplified framework to illustrate how a stricter requirement causes households to postpone saving to later stages in life. Moreover, we discuss how this postponement of saving affects households' timing of house purchases and their marginal propensity to consume over the life cycle. In Section 3, we present a fully-fledged quantitative model where the mechanisms of the simple framework are still at play, but where realistic features, such as housing and mortgage markets, are modeled explicitly.

2.1 The model

Consider a stylized life-cycle model of households, formulated in continuous time.[5] It is an endowment economy where households face an upward-sloping earnings profile over age t, and the household lives from age zero to T. The time-dependent income y_t is the only source of heterogeneity in the model. Households choose consumption c_t and savings in risk-free liquid bonds b_t to maximize their lifetime utility.

We add two constraints to this problem. The first is a classic borrowing limit that we set to zero, i.e., $b_t \geq \underline{b} = 0$. The second is a savings threshold $\bar{b} > \underline{b}$, such that households who save more than $\bar{b}$ receive a utility bonus Ψ. We regard the threshold $\bar{b}$ as a down-payment requirement, as it resembles the savings that are required in order to purchase a house. A household that chooses $b_t \geq \bar{b}$ is therefore considered to be a homeowner, whereas a household that saves less is referred to as a renter. The utility bonus Ψ is a reduced-form benefit that households attach to owning housing relative to renting.[6] We assume that this utility from homeownership is additively separable from the utility of consumption, an assumption that we relax in the quantitative model in the next section. For simplicity, we assume that households do not discount the future ($\beta = 1$) and the interest rate on savings in risk-free bonds is zero ($r = 0$). The households' dynamic problem is then characterized by

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

The household problem has three potential solutions: zero savings, positive savings smaller than $\bar{b}$, and savings exactly equal to $\bar{b}$. At each non-convexity, i.e., at $b_t = 0$ and $b_t = \bar{b}$, the household consumes its income, $c_t = y_t$, and saves nothing. In the first corner solution, the household is a renter with no accumulated savings. In the second corner solution, the household is a homeowner, but has no additional liquid savings. Hence, these two types of households resemble poor HtM and wealthy HtM households, respectively.

[5]The continuous-time formulation allows us to find analytical solutions for when households decide to save and when to become homeowners. In Appendix A, we present a discrete-time version of this model. We first study a setting with only two periods to highlight that changing the down-payment requirement is fundamentally different from changing the traditional borrowing constraint. We then analyze a setting with multiple periods and show that the results are equivalent to those in this section.

[6]It is common in the literature to assume that owned housing is associated with higher utility than rental housing. See e.g., Kaplan et al. (2020).

In the interior solution, where $0 < b_t < \bar{b}$, the household smooths consumption perfectly, $\dot{c}_t = 0$, according to the Euler equation. These households resemble unconstrained renters. When savings have reached the required down payment $\bar{b}$, the household has no incentive to accumulate any further wealth, since earnings is an increasing function of age.

Label the point at which households start to save by $\hat{t}$ and the period at which the down payment is reached by $\bar{t}$. Since consumption is constant in all periods in which the household saves, consumption is given by the income at time $\hat{t}$ during all these periods, i.e., $c_t = y_{\hat{t}} \; \forall \; t \in]\hat{t}, \bar{t}[$. Hence, the time of purchase $\bar{t}$ satisfies

$$\bar{b} = \int_{\hat{t}}^{\bar{t}} (y_t - y_{\hat{t}}) dt, \tag{1}$$

where $y_t - y_{\hat{t}}$ is the saving at each point in time. Since $y_{\hat{t}}$ depends on $\hat{t}$, the purchase timing is a function of when a household starts to save, i.e., $\bar{t} = \bar{t}(\hat{t})$. By applying Leibniz' integral rule to equation (1), the purchase timing depends on $\hat{t}$ as follows

$$\frac{d\bar{t}}{d\hat{t}} = \frac{\dot{y}_{\hat{t}} \left(\bar{t} - \hat{t}\right)}{y_{\bar{t}} - y_{\hat{t}}}. \tag{2}$$

Since income is upward-sloping, $\dot{y}_{\hat{t}} > 0$ and $y_{\bar{t}} > y_{\hat{t}}$, which implies that the expression is positive for all $\hat{t}$. Thus, whenever a household decides to start saving at a later point in time, they also delay the house purchase. Furthermore, note that equation (2) is a measure of the concavity of the income profile at time $\hat{t}$. It implies that the more concave the income profile, the larger the delay in the house purchase.

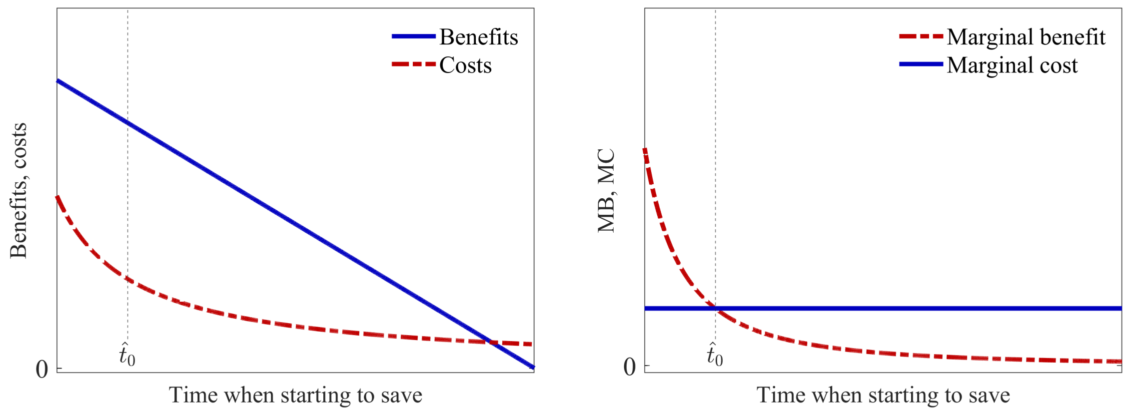
The intuition for why households buy a house later is quite simple. Whenever a household starts to save later, their consumption is higher in every period they save. The combination of postponing when to start saving and increased consumption while saving means that it takes longer for the household to accumulate the required down payment.

2.2 What is the optimal time to start saving?

The value function of the household is given by

$$V(\hat{t}) = \int_0^{\hat{t}} u(y_t)dt + \int_{\hat{t}}^{\bar{t}} u(y_{\hat{t}})dt + \int_{\bar{t}}^{T} u(y_t)dt + (T - \bar{t})\Psi. \tag{3}$$

It is useful to contrast this to the value of not saving up for the down payment at all. In that case, consumption equals income in all periods. The net benefit of starting to save at time $\hat{t}$ is given by the difference in value between saving up for the down payment as



(a) Benefits and costs

(b) Marginal benefit and marginal cost

Figure 2: Total benefits and costs, and marginal benefit and cost of delaying saving, as functions of the time when starting to save for the down payment.

compared to not saving at all, i.e.,

$$\tilde{V}(\hat{t}) \equiv V(\hat{t}) - \int_0^T u(y_t)dt = (T-\bar{t})\Psi - \int_{\hat{t}}^{\bar{t}} (u(y_t) - u(y_{\hat{t}}))dt. \tag{4}$$

The above equation illustrates the trade-off when choosing to save for the down payment. On the one hand, by saving, the household enjoys the extra utility Ψ for all the remaining periods after becoming a homeowner at time $\bar{t}$. This is the first term of the expression, which captures the benefit of saving. On the other hand, the household incurs a cost when saving for the down payment as it must forgo consumption in those periods. This cost is captured by the second term of the expression.

The benefit and cost as functions of $\hat{t}$ are illustrated by the solid and dashed lines in Figure 2a, for a linear upward-sloping income profile. The benefit is decreasing in $\hat{t}$ since the household enjoys fewer periods as a homeowner if it starts to save later. The cost is also decreasing in $\hat{t}$, and it is falling more rapidly the younger the household. This follows directly from the concavity of the utility function and the increasing income profile. The intuition is that, by starting to save later, the household replaces relatively costly periods of saving in utility terms with less costly periods.

The problem of the household is to choose the optimal time $\hat{t}$, such that the difference between benefits and costs is maximized. This is pinned down by the first-order condition of equation (4) with respect to $\hat{t}$, which yields

$$\Psi \frac{d\bar{t}}{d\hat{t}} = u'(y_{\hat{t}})\dot{y}_{\hat{t}}(\bar{t}-\hat{t}) - \left[u(y_{\bar{t}}) - u(y_{\hat{t}})\right]\frac{d\bar{t}}{d\hat{t}}. \tag{5}$$

The left-hand side captures the reduction in benefits from marginally delaying saving, i.e., the marginal cost. It is the utility loss of not receiving the bonus Ψ due to a delayed house purchase. The solid line in Figure 2b illustrates the marginal cost as a function of $\hat{t}$.

The right-hand side of the equation is the reduction in costs from marginally delaying saving, i.e., the marginal benefit. This is illustrated by the dashed line in Figure 2b. The marginal benefit consists of two parts. The first term captures that when a household chooses to postpone saving, its income is higher at the time it starts to save. As the income level is higher, the household consumes more throughout the stretch of time that it saves up for the down payment, yielding a higher level of utility. Due to the concavity of the utility function, this reduction in costs is stronger the lower the $\hat{t}$, which makes the marginal benefit curve slope downwards. The reduction in costs is dampened by the second term. As a marginal postponement in saving causes the household to buy a house later, it consumes less in those additional periods of saving. Because of the concavity of the utility function, the first term is always larger than the second, meaning that a delay in saving causes a reduction in costs.[7]

The solution to the household problem is to choose the timing $\hat{t}$ that equates the marginal cost and benefit of postponing saving. This point is denoted by $\hat{t}_0$ in Figure 2.

2.3 How does a higher down payment affect the timing of when to start saving?

To understand how the decision of when to start saving is affected by the down-payment requirement, we consider how the two sides of equation (5) are impacted by an increase in the requirement. To do so, start by noting that equation (5) can be further simplified, by using equation (2), as follows,

$$\Psi = g(\hat{t}), \tag{6}$$

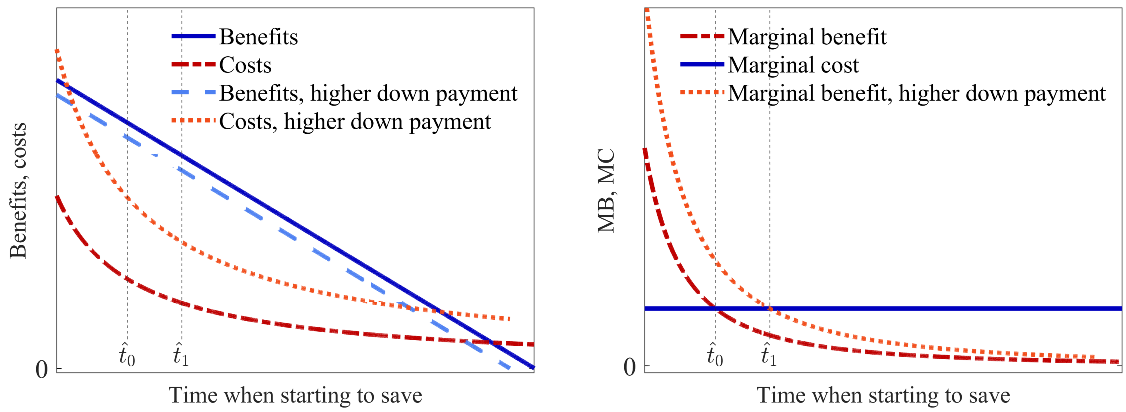
where

$$g(\hat{t}) \equiv u'(y_{\hat{t}})(y_{\bar{t}} - y_{\hat{t}}) + u(y_{\hat{t}}) - u(y_{\bar{t}}).$$

Next, we note that the derivative of the left-hand side of equation (6) with respect to $\bar{b}$ is equal to zero. Finally, the derivative of the right-hand side of equation (6), taking $\hat{t}$ as given, is

$$\frac{\partial\, g(\hat{t})}{\partial\, \bar{b}} = \left[u'(y_{\hat{t}}) - u'(y_{\bar{t}})\right] \dot{y}_{\bar{t}} \frac{\partial \bar{t}}{\partial \bar{b}}. \tag{7}$$

[7] This can easily be seen if using equation (2) to substitute for $d\bar{t}/d\hat{t}$ on the right-hand side of equation (5).



(a) Benefits and costs

(b) Marginal benefit and marginal cost

Figure 3: Total benefits and costs, and marginal benefit and cost of delaying saving, after the down-payment requirement is increased.

For a given time to start saving, the only way to save sufficiently for the higher requirement is to purchase at a later point in time, i.e., $\frac{\partial \bar{t}}{\partial \bar{b}} > 0$. Thus, equation (7) is positive for all $\hat{t}$.

Since $g(\hat{t})$ determines the marginal benefit of starting to save, this result implies a positive shift in the marginal benefit curve as illustrated in Figure 3b. The new equilibrium solution is $\hat{t}_1 > \hat{t}_0$. In other words, the time to start saving is postponed in response to a higher requirement. Consequently, as implied by equation (2), this also causes households to purchase the house at a later point in time.

What is the intuition behind this result? As seen in Figure 3a, a stricter down-payment constraint increases the cost of saving for any given $\hat{t}$, as the household has to save for a longer time. Importantly, the cost is increased by more in early periods of life, since the additional saving is more costly in utility terms when income and consumption are lower to begin with. This causes the cost curve to rotate, rather than making a parallel shift. As the cost curve becomes steeper, this also means that the marginal benefit curve shifts up. Intuitively, as the additional savings are more costly for younger ages as compared to older ones, the marginal benefit of postponing saving increases. As a result, the household is more inclined to shift saving from the early, expensive periods to later periods where the utility cost of saving is lower. This is also seen in equation (6), where we see that the marginal benefit of delaying saving is positively related to the income difference between the period when starting to save and when buying the house. A larger down payment leads to longer periods of saving, which increases this income difference. This makes it more favorable to postpone saving to replace relatively expensive periods of saving in utility terms with relatively cheap periods.

2.4 Implications for marginal propensities to consume

When studying the policy implications of changes to the down-payment requirement, as we do in Section 5, the distribution of MPCs is key. A primary determinant of households' MPC is access to liquidity. The fact that households adjust their life-cycle profile of savings, in response to changes in the down-payment constraint, has important implications for who is constrained and why.

In the simple model in this section, there are two groups of liquidity-constrained households with an MPC of 1. The first group comprises households that choose $b_t = 0$. These represent the poor HtM households and are characterized by their lack of wealth. All households below the age of $\hat{t}$ fall into this category. The second group are the wealthy HtM households that choose $b_t = \bar{b}$. While these households have positive wealth, they are unwilling to use their savings to smooth any negative income shock, as doing so would imply that they have to sell their house and lose the utility from homeownership. This group encompasses households aged above $\bar{t}$.

As shown above, a stricter down-payment constraint increases both $\hat{t}$ and $\bar{t}$. As a result, with a higher requirement a household spends a longer time as poor HtM and a shorter period as wealthy HtM. This change in the composition towards more poor HtM households comes with a range of policy implications, and is something that we dig deeper into in our quantitative exercises in Section 5.

2.5 How general are these results?

So far, all results are derived under the assumption that equation (5) pins down the solution to the households' maximization problem. This requires that the second derivative of $\tilde{V}(\hat{t})$ in equation (4) is negative, i.e.,

$$\tilde{V}''(\hat{t}) = \left[-\Psi + g(\hat{t})\right] \frac{d^2\bar{t}}{d\hat{t}^2} + g'(\hat{t}) \frac{d\bar{t}}{d\hat{t}} < 0.$$

First, notice that in equilibrium equation (6) holds, which means that $-\Psi + g(\hat{t}) = 0$. From equation (2), we also know that $d\bar{t}/d\hat{t} > 0$. Hence, for $\hat{t}$ to be a solution to the maximization problem, we require $g'(\hat{t}) < 0$. We have

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

Hence, the condition $g'(\hat{t}) < 0$ is satisfied when

$$\frac{u''(y_{\hat{t}})}{\frac{u'(y_{\bar{t}})-u'(y_{\hat{t}})}{y_{\bar{t}}-y_{\hat{t}}}} > \frac{\dot{y}_{\bar{t}}}{\frac{y_{\bar{t}}-y_{\hat{t}}}{\bar{t}-\hat{t}}}. \tag{8}$$

The left-hand side is a measure of the degree of concavity of the utility function. With a concave utility function, the numerator is a larger negative number than the denominator, which means that the left-hand side is a positive number larger than 1. The right-hand side is a measure of the degree of convexity of the income profile. If the income profile is convex, the slope of the income profile is always increasing and the right-hand side is larger than 1. For a linear income profile, the slope is constant, and the right-hand side is exactly equal to 1. Whenever income is concave, the slope is decreasing in t and the right-hand side is strictly below 1.

Hence, with concave utility, the condition in equation (8) holds for income profiles that are concave or linear. It also holds for convex income profiles if the convexity is not "too strong" relative to the concavity of the utility function. However, since estimated life-cycle income profiles are typically concave, we regard this result to be quite general. In Appendix B, we examine this condition further and discuss the intuition.[8]

The fact that $g'(\hat{t})$ is negative under relatively weak conditions implies that households' decision to delay saving in response to a stricter requirement is also a quite general result. To see why, recall from equation (7) that $g(\hat{t})$ increases with $\bar{b}$. With $g'(\hat{t}) < 0$, it follows that $\hat{t}$ has to increase to restore the equilibrium pinned down by equation (6). In other words, whenever the model has an interior solution, such that $0 < \hat{t} < T$, an increase in the required down payment always results in a postponement of saving, as well as a delayed house purchase.

3 A model of the U.S. economy

The model in the previous section captures the main trade-off that determines when to start saving for the down payment and when to buy a house. However, there are some features of the model that, when relaxed, may impact the strength of the mechanisms. First, we have so far only considered an extensive-margin decision related to housing, while a stricter constraint may also affect the intensive margin, i.e., the optimal house size. Second, the simple model does not include a retirement phase. The desire to save for retirement is arguably an important savings motive for working-age households, alongside

[8] In particular, Appendix B.1 provides necessary conditions. In Appendix B.2, we provide a closed-form solution for the case of an exponential income profile, which is highly convex. We demonstrate that even this type of income profile is consistent with our results. Appendix B.3 provides step-by-step calculations for the equations derived in this section.

the incentive to save for the house. Third, there is no earnings risk in the simple model. With earnings risk, households hold precautionary savings, which impacts households' MPCs. Fourth, the illiquid nature of housing and mortgages needs to be included. Houses are costly to buy and sell, cash-out refinancing is not always possible, and mortgages are typically long-term contracts with pre-specified repayment plans.

To address these concerns, 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 an LTV constraint. To further capture the constraints in the U.S. housing market, households also have to comply with a PTI requirement, and mortgages are long-term and subject to amortization plans. To smooth consumption, households may use cash-out refinancing to access their housing equity, but this comes at a cost.

The assets in the model are houses and risk-free liquid bonds. The only source of debt is mortgages. The supply of both mortgages and bonds is fully elastic, and the returns are exogenous. In the benchmark analysis we assume that aggregate housing supply is also fully elastic in the long run, which implies that house prices are unaffected by changes to the down-payment constraint. In Appendix F.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.[9]

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

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

shocks that older people often experience.

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

$$\log(y_{ij}) = \alpha_i + g(j) + n_{ij} + \nu_i \quad \text{for } j \leq J_{ret}, \tag{9}$$

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,

$$\log(y_{ij}) = \min\left(\log(R) + \log(z_{i,J_{ret}}),\ \log(B^{max})\right) + \nu_i \quad \text{for } j > J_{ret}. \tag{10}$$

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).

In our baseline setting, 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 house size available for purchase is larger than the smallest size available for rent.[10] There are transaction costs associated with both buying and selling a house. These costs are proportional to the house value, and are given by the parameters ς^b and ς^s, respectively.

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

[10] 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).

where

$$\chi_j = \left(\sum_{k=1}^{M_j} \left[\frac{1}{(1+r_m)^k} \right] \right)^{-1}. \tag{11}$$

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 (11) can use cash-out refinancing by paying a fixed cost ς^r.

The use of mortgage financing is further limited by the PTI constraint and the down-payment requirement. Whenever a household takes up a new mortgage, either when buying a new home or when using cash-out refinancing, these constraints need to be fulfilled. The down-payment requirement is a fraction θ of the house value. Thus, the amount of housing equity needed to abide with the down-payment constraint can be stated as follows

$$p_h h' - m' \geq \theta p_h h', \tag{12}$$

where h' is the chosen quantity of housing and p_h is the price per unit of housing. 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,

$$\chi_{j+1} m' + (\tau^h + \varsigma^I) p_h h' \leq \psi z. \tag{13}$$

The housing-related payments also include property taxes τ^h, and home insurance payments ς^I, both proportional to the house value.[11]

Households have two ways of saving in the model. One way 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 with positive mortgage balances may still want to save in liquid bonds for precautionary reasons.

Preferences. Households have CRRA preferences over a Cobb-Douglas aggregator of

[11] 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.

non-durable consumption c and housing services s.

$$U_j(c,s) = e_j \frac{\left(c^{\alpha} s^{1-\alpha}\right)^{1-\sigma}}{1-\sigma}, \tag{14}$$

where e_j is an age-dependent utility shifter that captures the tendency of household size to vary with the life cycle (see, e.g., Kaplan et al. (2020)). Non-durable consumption is the numeraire good in the model. There is a linear technology that transforms owned housing units h' to housing services s, such that $s = (1+\Psi)h'$ if $h' > 0$. Thus, owned housing translates into more housing services than the equivalent rental housing unit provides. The added service given by Ψ represents the additional utility that households derive from ownership. Moreover, homeowners enjoy the full housing services provided by their house and are not allowed to rent out part of their property.

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

$$U^B(q') = \upsilon \frac{(q')^{1-\sigma}}{1-\sigma} \qquad \text{for } j \in [J_{ret}, J], \tag{15}$$

where υ controls the strength of the bequest motive, and bequests q' are given by the net worth of a household,

$$q' = b' + p_h h' - m'. \tag{16}$$

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.

$$\Gamma \equiv \mathbb{I}^w \tau^{ss} y + \tau^h p_h h + T(\tilde{y}), \tag{17}$$

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

$$x \equiv \begin{cases} (1+r)b - (1+r^m)m + y - \Gamma - \delta^h h + (1-\varsigma^s)p_h h & \text{if } j > 1 \\ y - \Gamma + a & \text{if } j = 1, \end{cases} \tag{18}$$

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

$$\underbrace{c + b' + \mathbb{I}^R p_r s + \mathbb{I}^B (1+\varsigma^b) p_h h' + \mathbb{I}^{RF,S}(1-\varsigma^s)p_h h + \mathbb{I}^{RF}\varsigma^r}_{\text{“Expenditures”}} \leq \underbrace{x + m'}_{\text{“Money to spend”}} \tag{19}$$

$$p_h h' - \mathbb{I}^{B,RF} m' \geq \theta p_h h' \qquad \text{Down-payment constraint}$$

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

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

$$s = (1 + \Psi) h' \qquad \text{if } h' > 0$$

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

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

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

Equation (19) states the household's budget constraint. The variables $\mathbb{I}^k$ are indicator variables that equal one for the relevant case $k \in \{R, B, S, RF\}$, and zero otherwise. These capture that only renters pay rent, only refinancers pay the refinancing cost, and only if you buy or sell a house do you pay the associated transaction costs. In addition, only house buyers and households who refinance their mortgage have to comply with the down-payment and PTI requirements, while other homeowners have to adhere to the minimum-payment requirement of the amortization schedule. The solution to the household problem is given by

$$\begin{aligned} V_j(z, x, h, m) = \max \Big\{ & V_j^R(z, x, h, m), V_j^B(z, x, h, m) \\ & V_j^S(z, x, h, m), V_j^{RF}(z, x, h, m) \Big\}, \end{aligned} \tag{20}$$

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,

$$p_r = \frac{1}{1 + r} \Big[r p_h + \delta^r + \tau^h p_h \Big]. \tag{21}$$

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 $\tau^h p_h$.[12] Since the operating expenses are realized in the next period, these costs are discounted at the required rate of return of the investors.

3.3 Government

The role of the government in the model is to tax households and rental firms, and provide social security benefits to retirees. Overall, the government runs a surplus, which it spends on activities that do not affect the other agents in the economy.

The government collects property taxes from the rental firms, and taxes the households using three different taxes, as described in equation (17). The labor income tax is modeled using a non-linear tax and transfer function $T(\tilde{y})$, as in Heathcote et al. (2017). This function is continuous and convex, and is meant to proxy for the progressive federal earnings taxes in the U.S.

$$T(\tilde{y}) = \tilde{y} - \lambda \tilde{y}^{1-\tau^p}, \tag{22}$$

where λ governs the level of the income tax, and τ^p controls the degree of progressivity. The argument $\tilde{y}$ is taxable labor income, which consists of labor income or social security benefits, net of deductions. If beneficial, a household deducts mortgage interest payments and property taxes before paying labor income taxes. Thus, we include some of the main features of the U.S. tax code with respect to housing; that is, imputed rents are not taxed, mortgage interest payments and property taxes are deductible, and labor income after deductions is subject to a progressive tax schedule.

4 Calibration

We calibrate the model to the U.S. economy. As our aim is to capture a steady state of the economy, we conduct the calibration using long-run averages of parameter values and moments.

[12] 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)).

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 calibrate the remaining parameters internally by matching model moments to their data counterparts.

Parameter	Description	Value
σ	Coefficient of relative risk aversion	2
τ^{ss}	Social security tax	0.153
τ^{h}	Property tax	0.01
r	Interest rate, bonds	0
r^{m}	Interest rate, mortgages	0.04
θ	Down-payment requirement	0.10
ψ	Payment-to-income requirement	0.177
δ^{h}	Depreciation, owner-occupied housing	0.03
ς^{I}	Home insurance	0.005
ς^{b}	Transaction cost if buying house	0.025
ς^{s}	Transaction cost if selling house	0.07
R	Replacement rate for retirees	0.5
B^{max}	Maximum benefit during retirement	61.5

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

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

Idiosyncratic earnings. To estimate the earnings process in equation (9), we use data from the Panel Study of Income Dynamics (PSID), survey years 1970 to 1992. In the estimation of the age-dependent components of earnings $g(j)$, we follow Cocco et al. (2005).[13] 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 (10), 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

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

Security Administration.

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

Table 2: Estimated variances of earnings shocks

Note: Household earnings contain a fixed household component. Throughout working life, earnings are subject to permanent and transitory shocks, while in retirement there is only transitory earnings risk. Estimated with PSID data, years 1970 to 1992.

Assets and mortgages. To match the distribution of wealth and the correlation between earnings and wealth among the young, we distribute initial assets a to the newborn cohort in the model similarly to Kaplan and Violante (2014). In the model, we divide newborns into 21 equally-sized groups based on their earnings. The probability of being born with initial assets and the amount of these assets vary across earnings bins. These probabilities and amounts are based on data from the Survey of Consumer Finances (SCF). Specifically, we divide households of age 23-25 in the SCF for survey years 1989 to 2019 into 21 equally-sized groups based on their reported earnings. We assume that a household has positive initial assets in the data whenever its asset holdings are larger than 1,000 in 2019 dollars. Within each earnings bin, we compute the share of households that meet this requirement and the median net worth of these households. For each bin, we scale the median net worth by median earnings for the working-age population in the data. We then rescale by median earnings in the model when we allocate the initial assets to households in the model economy.

Using yearly data from 1989 to 2019 on 3-month Treasury bill rates, deflated by the Consumer Price Index (CPI), the mean real rate is 0.45 percent.[14] 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 3.9 percent. This is computed from the Federal Reserve's series of the average contract rate on 30-year fixed-rate mortgage commitments, deflated by the CPI. Hence, we choose a yearly mortgage interest rate of 4 percent.

Between 1976 and 1992, the average down payment of first-time buyers in the U.S. ranged from 11 to 21 percent of the house value (U.S. Bureau of the Census, Statistical Abstract of the United States (GPO), 1987, 1988, and 1994). We use the lower bound of this interval, and set the down-payment requirement θ for new mortgages to 10 percent, as this helps us to capture the upper tail of the LTV distribution. In Appendix F.7, we show that our main results remain if we instead set the down-payment requirement to 20

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

percent in the baseline calibration. Our main results also hold if we add a cost for those who take up a mortgage with an LTV above 0.8, representing the mortgage insurance that is required for high-LTV non-FHA loans in the U.S., as shown in Appendix F.6. The PTI 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. We conduct a robustness analysis with respect to this value in Appendix F.9. The depreciation rate of owned housing is taken from Harding et al. (2007) who estimate the median depreciation rate of owned housing, gross of maintenance, to be 3 percent. The transaction costs for buying and selling a house are set to 2.5 and 7 percent of the house value, respectively. These values are taken from Gruber and Martin (2003). The home insurance rate ς^I is set to 0.005 percent of the house value, which is in line with the median property insurance payment in the 2013 American Housing Survey (AHS).

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

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

4.2 Internally calibrated parameters

The parameters that are calibrated to match a set of data moments are listed in Table 3. Unless otherwise noted, we use data from the SCF, pooled across the 1989 to 2019 survey years. As it is in general difficult for this class of models to match the strong skewness in wealth, we choose to focus on the bottom 90 percent of the population in terms of net worth in the SCF. The saving and consumption choices of the very wealthy individuals presumably do not depend much on the down-payment requirement, thus, restricting our attention to the bottom 90 percent should not materially affect our findings. All parameters in Table 3 are jointly calibrated, taking the independently calibrated parameters in Table 1 as given.[15]

The consumption weight in the utility function α controls the share of expenditures that is allocated to consumption versus housing services. This weight is set to 0.764 to

[15]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 (21). See Appendix C and D for a detailed description of the equilibrium definition and the solution method.

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

Table 3: Internally calibrated parameters

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

match the median house value-to-earnings ratio, among the working-age homeowners. The discount factor β affects the saving decisions. It is therefore used to match the mean net worth over mean earnings, among households of age 23 to 64. The resulting yearly discount factor is 0.953. To capture the strength of the bequest motive, the utility shifter of bequests υ is used to match the median net worth of households aged 75 over the median net worth of households aged 50. The parameter value is calibrated to be 4.2.

The decision to buy a house instead of renting housing services is affected by a number of factors in the model. Households generally prefer to own, however, frictions in the mortgage and housing markets stop some households from doing so. The positive net benefit of owning is due to the utility bonus of owning, the lower depreciation rate of owned housing, as well as the preferential tax treatment of housing and mortgage, i.e., mortgage interest payments and property taxes are deductible and imputed rents are left untaxed. The utility bonus of owning Ψ impacts the timing of the first house purchase, which in turn affects the average size of owned housing relative to rented housing. The utility bonus is calibrated to be 0.3. The higher depreciation rate of rental housing also incentivizes households to buy when they are younger. Therefore, we calibrate the depreciation rate of rental housing δ^r to match the homeownership rate among the relatively young households, aged 30 to 40. The minimum house size available for purchase $\underline{h}$, 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 2 530 in 2019 dollars, we match the 8 percent refinancing rate among homeowners as stated in Chen et al. (2020).[16]

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

[16] A robustness exercise with respect to the refinancing cost is performed in Appendix F.8.

to 1.6975, to match the average marginal earnings tax rate after deductions among the working-age population. The progressivity of the earnings tax is controlled by parameter τ^p. This parameter is set to 0.142, to minimize the sum of the absolute difference between the fraction of households exposed to the different statutory tax brackets in the data compared to the model. Since the tax schedule is continuous in the model, households are allocated to their nearest tax bracket in the data for this calibration exercise. The data on tax rates is taken from Harris (2005).

4.3 Data versus model: distributions

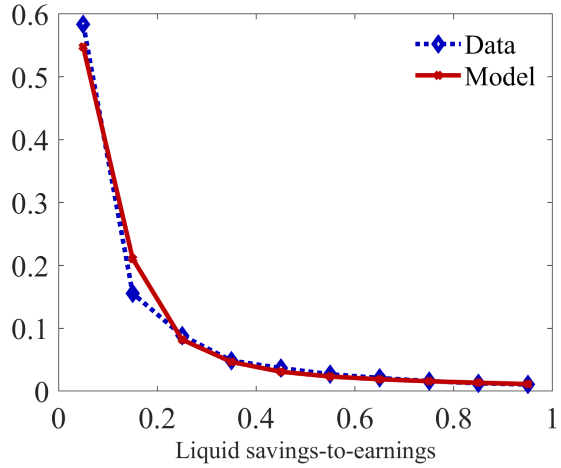
In Section 5, we examine the implications of a stricter down-payment requirement for the distribution of MPCs, and in turn policy. Since the distribution of MPCs depends on how constrained households are, it is important to compare cross-sectional features of our model against the data for variables that can indicate if households are constrained. Figures 4a-4c show the distributions of liquid savings-to-earnings, LTVs, and house value-to earnings for the model and for the data from the SCF.[17] These distributions are relevant as they indicate the size of households' buffers that can be used to cushion an unexpected fall in income. Overall, the model does an excellent job in terms of matching the distributions of liquid savings and debt, which are both untargeted variables in the calibration. The model also successfully matches the timing of house purchases among households up until retirement as seen in Figure 4d, which the simple life-cycle model in Section 2 suggests is an important margin of adjustment when the down-payment constraint changes.

4.4 Empirical literature versus model: a validation exercise

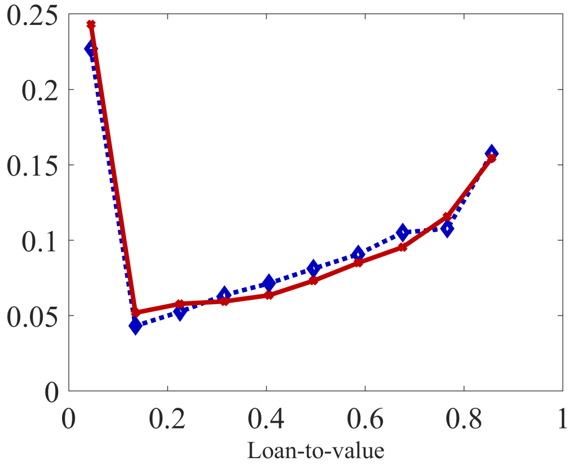
To further validate the model, we compare the model's predictions to estimates in the empirical literature. The two empirical papers most closely related to our work are Aastveit et al. (2020) and Van Bekkum et al. (2024). Similar to us, they study the effects of an increase in the down-payment requirement on households' choices. However, whereas they estimate the short-run effects of introducing stricter constraints, we study the long-run effects. Moreover, their findings regard local average treatment effects of the policy, whereas we use a model to highlight and quantify how a tightening of the constraint also leads to changes in behavior among households far away from the constraint.

Their empirical strategy is to identify households who are likely to be directly affected by the change in the down-payment policy, and compare how the choices of these households

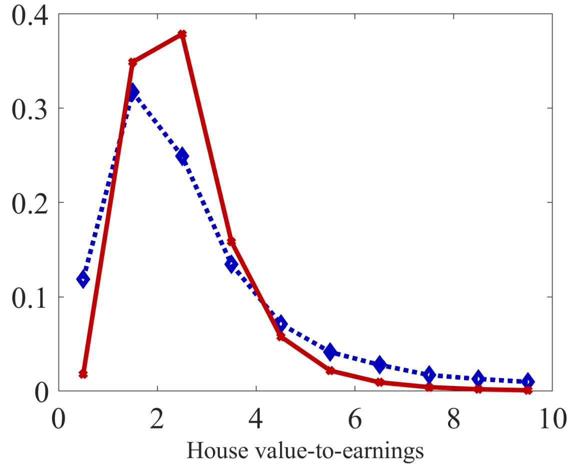
[17]We define liquid savings in the SCF as the sum of cash, checking, savings, money market, and call accounts, prepaid cards, directly-held mutual funds, stocks, and bonds, less any credit card debt balance. Cash is assumed to be five percent of the balance in the variable *liq* in the SCF, similar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



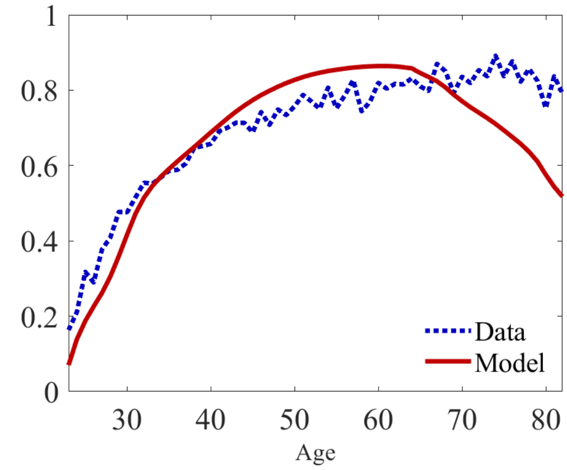
(a) Distribution, liquid savings-to-earnings



(b) Distribution, loan-to-value



(c) Distribution, house value-to-earnings



(d) Homeownership rate over life cycle

Figure 4: Comparison of data and model

Note: Figures 4a-4c divide households into bins according to the variable of interest and illustrate the share of households in each bin. Every marker is the mid-point of each bin. Figure 4d shows the share of homeowners at each age. The data in all figures are from the SCF, survey years 1989-2019. Model refers to the baseline economy. In Figure 4a and Figure 4c, only working-age households are included, and Figure 4b only displays homeowners.

change relative to a control group comprised by households that are not directly affected by the policy change. More specifically, affected households need to fulfil 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.[18]

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

[18]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.

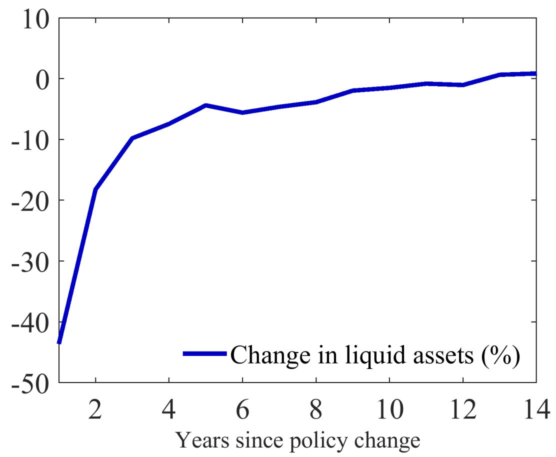


Figure 5: Mean change in bond holdings for affected house buyers

Note: The mean change in holdings of liquid bonds in each period after a house purchase relative to the steady state, among affected households,. 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.

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 could have implications for households' MPCs.

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 5 plots the mean liquid asset holdings after the policy implementation relative to the steady state, for the affected households. Compared to the liquid asset holdings in the absence of the reform, i.e. in 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 close to the level in the counterfactual steady-state analysis. This relatively fast convergence is similar to what Van Bekkum et al. (2024) find for the Netherlands.

The model also performs well in matching other results in Aastveit et al. (2020) and Van Bekkum et al. (2024). For example, the overall mortgage issuance falls and a substantial share of homeowners delay their house purchase. Thus, the effect on the extensive margin of house purchases is relevant also in the short run. Overall, our results of the short-run implications of changing the down-payment requirement are qualitatively in line with the results in the empirical literature.

5 Quantitative effects of down-payment requirements

Equipped with our model, we proceed with the quantitative analysis.[19] We first examine the impact of permanent changes to down-payment requirements on saving and housing decisions. After this assessment, we analyze the implications for MPCs and address the broader effects for both monetary and fiscal policy. As a final point, we explore the welfare costs of down-payment requirements and how they differ across the income distribution.

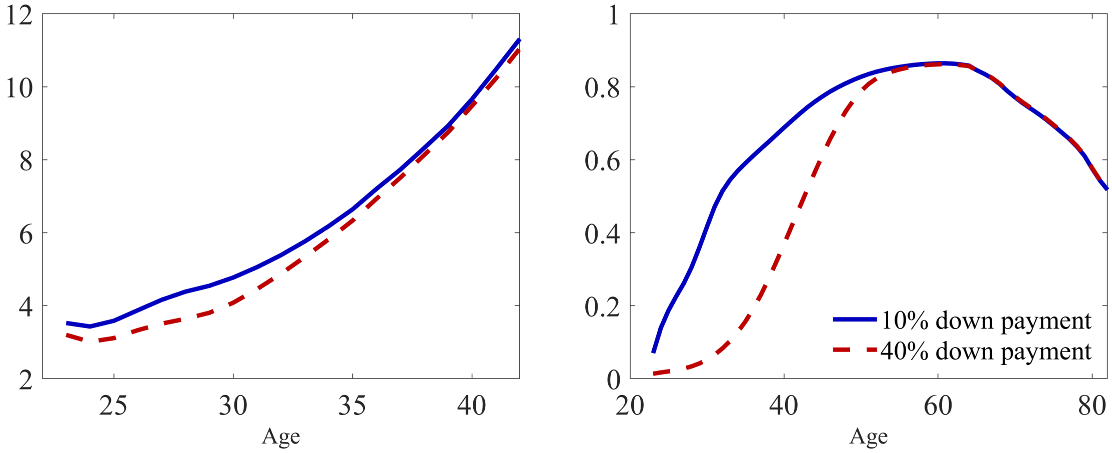
5.1 Housing and saving choices

We begin by comparing our baseline setting with a down-payment constraint of 10 percent to an economy where the requirement is 40 percent. This is a substantial increase in the constraint and it is mainly chosen to clearly illustrate the mechanisms of the model. In Figure 6a, we see that the mean liquid savings are reduced among young renters when the down-payment constraint is stricter. The same mechanism as in the simple life-cycle model in Section 2 applies. The cost of saving in terms of foregone consumption increases, and more so for younger households with lower earnings. For any given time to start saving, households need to save for a longer period when the down payment is higher. As described in Section 2, this is especially costly for young households due to their high marginal utility of consumption. Thus, when the required down payment is larger, the marginal benefit of postponing saving increases and many households therefore wait longer before starting to save for the down payment.

The delayed saving in combination with the larger down-payment make young households buy a house later in life, as seen in Figure 6b. In addition to this extensive-margin response, we also find that households choose houses of smaller size/lower quality in response to the stricter requirement, as seen in Figure 15 in Appendix F.1.

The saving and housing responses to a stricter down-payment constraint are also clearly illustrated by considering how certain groups of house buyers adjust their behavior. Figure 7 presents the saving and housing adjustments of households who buy their first house at age 30 if the down-payment requirement is 10 percent. We note that the responses to a stricter constraint are quite heterogeneous, as the homeownership rate of these households

[19] In Appendix A.2, we present a discrete-time version of the simple model in Section 2 and show that the main results are remarkably similar to the quantitative results in this section.

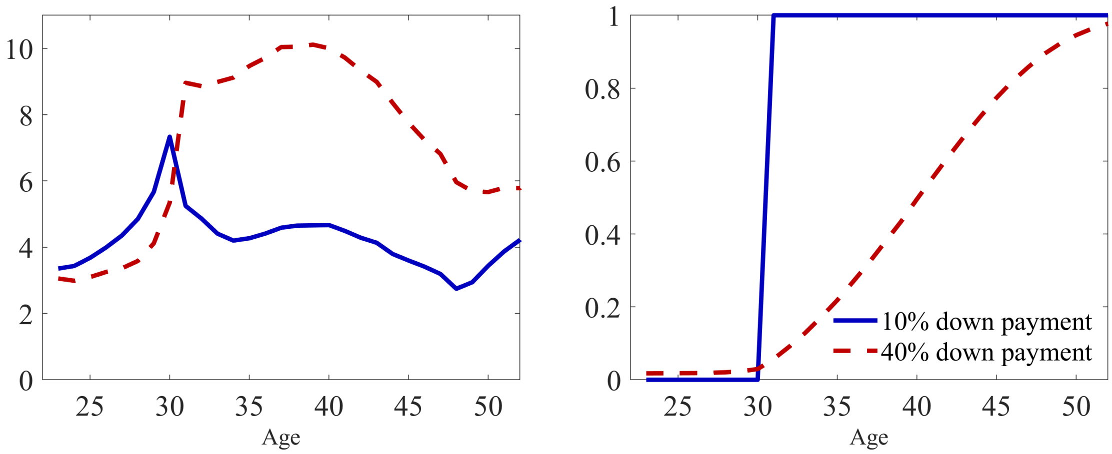


(a) Renters' average liquid savings

(b) Homeownership rate

Figure 6: Effects over the life cycle of a larger down-payment requirement
Mean liquid savings by age are computed for those who are renters in both scenarios, i.e., the economy with a 10 percent and a 40 percent down-payment constraint.

gradually increases up until age 50 in the alternative scenario. It is also clear that these households postpone saving for the down payment when the constraint is stricter, as seen by the lower mean liquid savings up until age 30. After age 30 there is an increase in liquid savings resulting from the higher share of renters, who now save a larger amount before buying a house.



(a) Mean liquid savings

(b) Homeownership rate

Figure 7: Effects on those buying a house at age 30 when the requirement is 10 percent

5.2 Marginal propensities to consume

Since a stricter down-payment requirement substantially alters households' housing and saving choices over the life cycle, it could have important effects on households' MPC.

The MPC of household i of age j is defined as follows.

$$MPC_{ij} \equiv \frac{c_{ij}(z, x + \Delta_x, h, m) - c_{ij}(z, x, h, m)}{\Delta_x}, \tag{23}$$

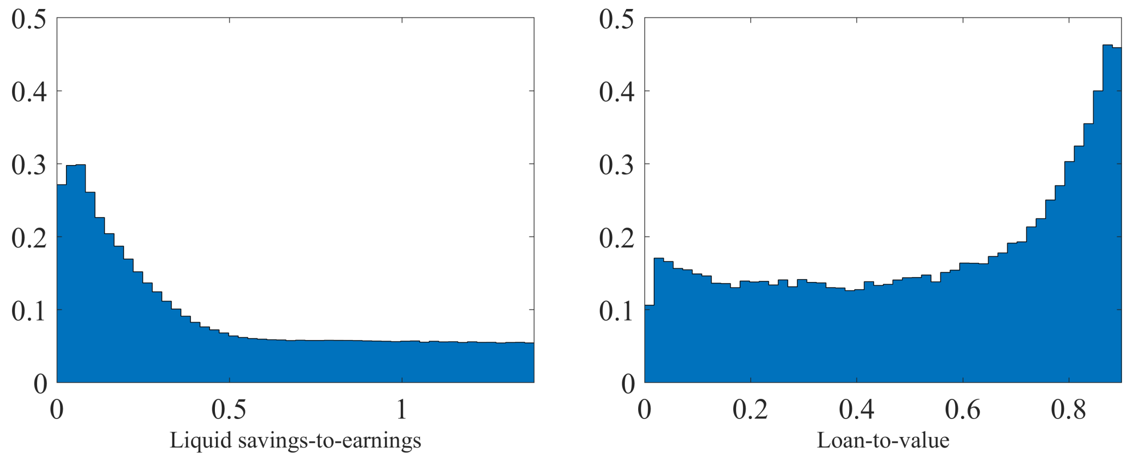
where $c_{ij}(z, x, h, m)$ is consumption for household i of age j if there is no shock, and $c_{ij}(z, x + \Delta_x, h, m)$ is consumption when there is an unexpected shock of size Δ_x to cash-on-hand. Intuitively, the MPC is the fraction of the shock Δ_x that is spent on non-housing consumption. In the baseline analysis, we consider a shock of -1 000 dollars.[20] This is a significant shock, but still small enough to ensure that all households have positive cash-on-hand. In Appendix F.3, we show that our main results are robust to other shock sizes and the sign of the shock.

5.2.1 The importance of liquid savings and debt

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 8a 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 be 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 a negative 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 a household's MPC in this model.

Figure 8b displays the mean MPC across homeowners with different LTV ratios. The MPC is clearly increasing in the LTV ratio. 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. Overall, these findings are broadly in line with empirical work by, e.g., Agarwal and Qian (2014); Broda and Parker (2014); Cloyne et al. (2019); Cloyne and Surico (2017); Fagereng et al. (2021); Misra and Surico (2014); Parker et al. (2013), who show that MPCs tend to vary substantially across the population depending on households' balance sheets.

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



(a) Mean MPC by liquid savings-to-earnings

(b) Mean MPC by LTV

Figure 8: Mean MPC 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.

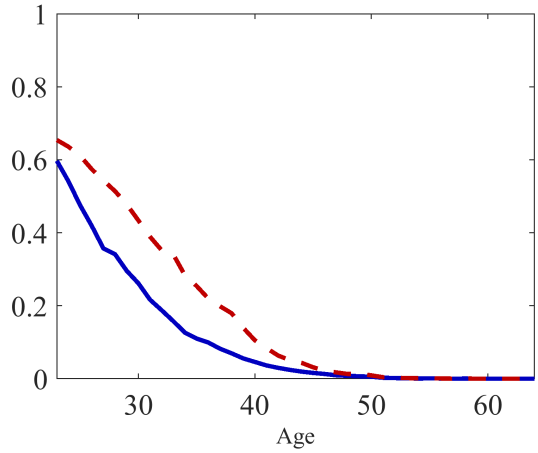
5.2.2 Down payments and the marginal propensity to consume

To examine the impact of a stricter down-payment requirement on households' MPC, we start by considering renters and homeowners separately. Since households start saving for the down payment later when the requirement is larger, there are potentially more liquidity-constrained renters, as suggested by the simple model in Section 2.[21] In Figure 9a we see exactly this. The share of poor HtM households is increasing up until age 50, when the down-payment constraint is changed from 10 to 40 percent. In contrast, Figure 9b shows that the share of wealthy HtM homeowners decreases. There are two reasons for the decline in the share of wealthy HtM. First, households are now older when they buy their first home, consistent with the simple model in Section 2. In addition, since the richer model includes the retirement phase, older house buyers are liquidity constrained for fewer periods as it takes a shorter time after the house purchase for their optimal savings for life-cycle reasons to exceed the required down payment.

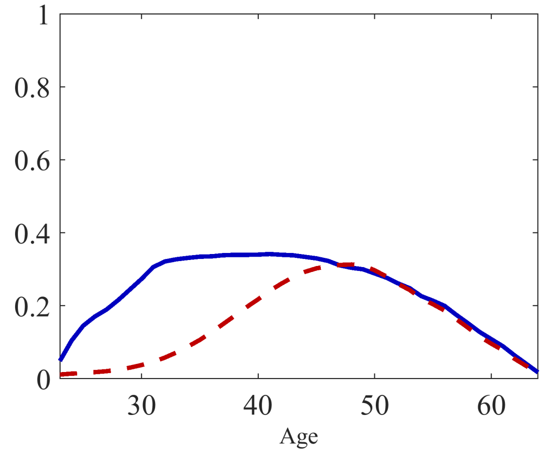
The effects on the shares of wealthy and poor HtM households translate into changes in the mean MPC over the life cycle. Figure 9c presents that the stricter down-payment constraint causes the mean MPC to increase slightly among the youngest households and to decrease among the middle-aged.

Figure 9d shows how the mean MPC changes for a range of down-payment requirements. The mean MPC in the baseline economy is approximately 19 percent, which we normalize

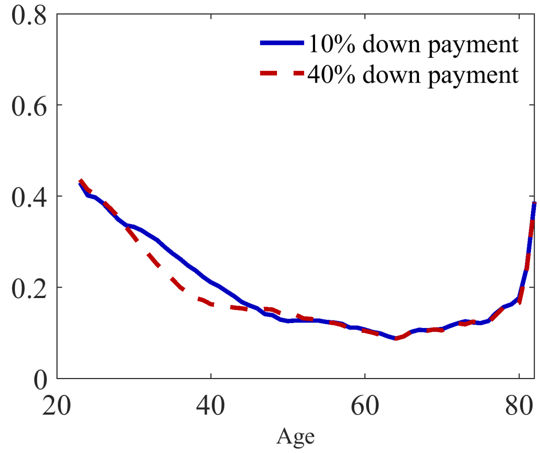
[21] As illustrated in Figure 8, there is no single household variable, such as liquid savings, that can summarize how constrained a household is. We therefore classify households as HtM according to their MPCs. In this section, we assume that a household is constrained if it has an MPC above 0.3. In Appendix F.4, we show that our results are similar for other threshold levels.



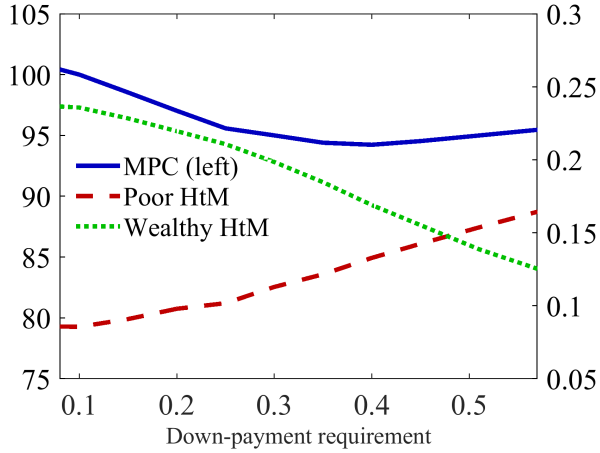
(a) Share poor HtM households



(b) Share wealthy HtM households



(c) Mean MPC



(d) Mean MPC and shares of wealthy and poor HtM

Figure 9: (a)-(c) Effects over the life cycle of a larger down-payment requirement. (d) Mean MPC (percent of baseline) and shares of wealthy and poor HtM households, across various down-payment requirements.

to 100 in the figure. We note that the mean MPC is slightly U-shaped in the down-payment constraint.[22] 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 as compared to its current level, when the down-payment requirement is 10 percent. This relatively modest effect on mean MPC is explained by the fact that the shares of poor and wealthy HtM households move in opposite directions when changing the constraint.

5.3 Implications for policy

A rich literature has emphasized the importance of households' MPCs for both fiscal and monetary policy (Auclert et al. (2018), Kaplan and Violante (2014), Auclert (2019), and

[22]The mechanisms behind this finding are discussed in detail in Appendix A.2 for the simple life-cycle model in discrete time.

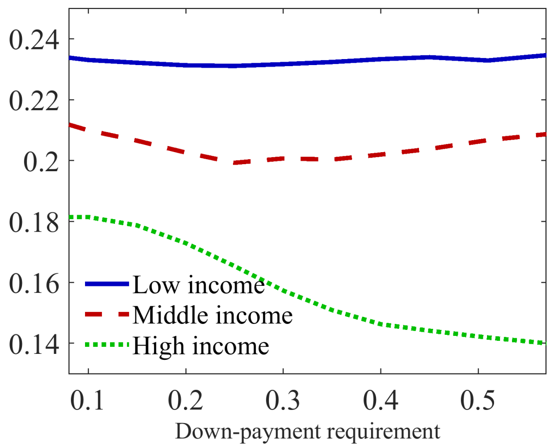


Figure 10: Mean MPC for different income groups, across down-payment requirements

Kaplan et al. (2018)). Thus, even if the effect on mean MPC is modest, the substantial distributional effects from changes to the down-payment requirement may still impact the aggregate responses to macroeconomic policy. In this section, we provide two examples of how changes to down-payment requirements influence the effects of policy. The first is related to fiscal policy, whereas the other is concerned with the transmission of monetary policy.

5.3.1 The aggregate consumption response to fiscal transfers

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 section suggest that there is considerable heterogeneity in how a household's MPC changes with the down-payment requirement. Thus, the way in which cash transfers should be distributed is likely to depend on the level of the constraint.

We begin by examining how a change in the down-payment constraint affects households with different income. Figure 10 displays the mean MPC of three groups of households with different income, and how their MPCs depend on the constraint.[23] 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 an unexpected cash transfer 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

[23] Specifically, households are allocated into three groups based on their income. Low income corresponds to households at the bottom 20 percent of the earnings distribution. High income household are the top 30 percent of the income distribution. The remaining households constitute the middle-income group.

of the constraint. Their mean MPC, on the other hand, is U-shaped in the down-payment requirement. 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 even higher levels of the down-payment requirement, many of the middle-income households delay saving for house purposes and become renters with little liquid savings and high MPCs.

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

To summarize, the MPCs of households with high income are the most affected by changes in the down-payment constraint. Low-income households, on the other hand, consistently have higher MPCs, but their MPCs are relatively unaffected by changes in the requirement. Thus, if cash-transfer schemes are at least partly motivated by a desire to increase aggregate consumption, targeting low-income households is increasingly important the larger the down payment.

These results are also important when considering effects of other changes to income, such as those caused by aggregate shocks or business-cycle fluctuations. For instance, in a standard neoclassical model with competitive markets, a shock to TFP translates into the same proportional change in earnings for all households.[24] This implies a larger absolute change for high earners, whose MPCs are lower under tighter down-payment constraints, implying a smaller response in aggregate demand. A shock that is instead skewed towards low-earning households generates an aggregate consumption response that is largely independent of the down-payment constraint.

5.3.2 What is the impact on the direct effects of monetary policy?

Since households' asset and debt choices depend on the down-payment constraint, households' exposure to monetary policy is also influenced by changes to the constraint. To examine how monetary policy is affected by 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, which have been shown to play a key role in the transmission of monetary policy (Calza

[24]We look at this scenario in Appendix F.10.

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 11a 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.[25] We see that the direct cash-flow effects of monetary policy are highly dependent on the down-payment constraint. At the current level of the requirement, consumption contracts by approximately 0.18 percent in response to the interest-rate increase. However, with a down-payment constraint of 30 percent the consumption response is approximately halved. At very strict levels of the constraint, the consumption response can even be positive.

The direct consumption response of the interest-rate shock follows from the effect the change in the interest rate has on different households' cash flows and how this effect correlates with MPCs. The dotted line in Figure 11a 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.

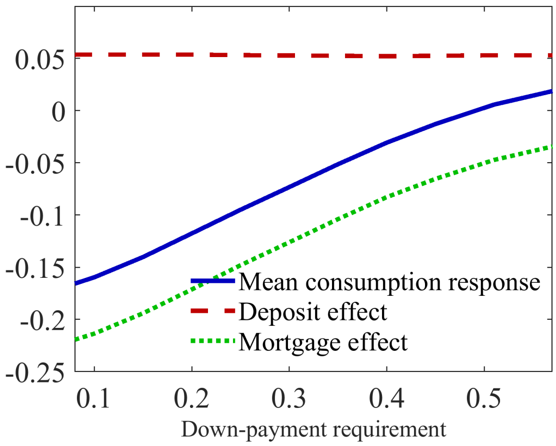
Second, the importance of the mortgage cash-flow channel can be substantial and varies greatly with the down-payment constraint. When the required down payment is small, many households have large mortgage balances, implying large changes in cash flows due to the interest rate shock. In addition, since 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 11b 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 can decline, it also makes monetary policy less potent. The reduced effectiveness is largely explained by a dampened mortgage cash-flow channel.

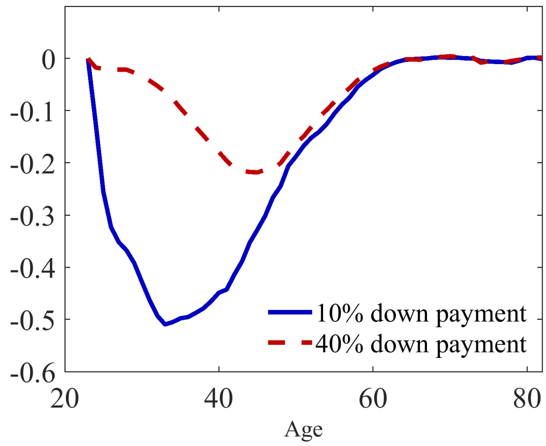
5.4 Welfare costs of stricter down-payment requirements

The fact that agents substantially adjust their saving and portfolio choices in response to a stricter constraint suggests that the welfare effects are non-negligible. Although

[25] For this exercise we assume that mortgages have adjustable interest rate.



(a) Consumption response



(b) Consumption response, mortgage effect

Figure 11: Mean consumption responses to a transitory one percentage point rise in the interest rate

our goal is not to make a full normative analysis of the total welfare effects of different down-payment constraints, it is informative to evaluate how costly a stricter requirement is from the perspective of the households.[26]

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

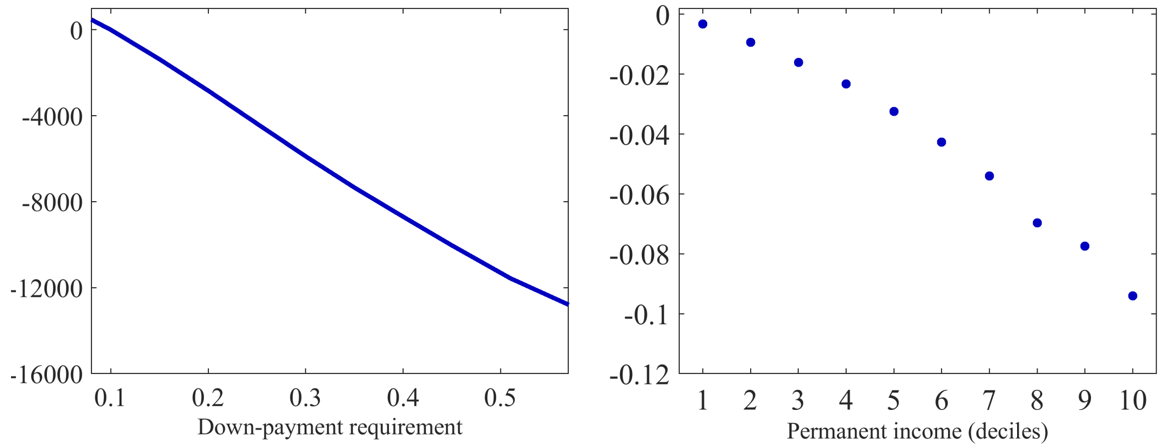
$$V_1^{new}(z_i, (1-\gamma_i)x_i, h_i, m_i) = V_1^{base}(z_i, x_i, h_i, m_i), \tag{24}$$

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

As illustrated in Figure 12a, the welfare costs of a stricter down-payment constraint are substantial. For example, on average households require a transfer of almost 3,000 dollars to make them equally well off in a setting with a 20 percent down-payment requirement as in the economy with a 10 percent constraint. To put this into perspective, this transfer is equivalent to 5.4 percent of the mean income of 23-year-olds.

Since we measure the total expected welfare effects over life, the only heterogeneity among households is their initial differences in income and net worth, which together make up a household's cash-on-hand x_i at age 23. Figure 12b illustrates how the welfare effects

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



(a) Average CV (USD) (b) Average CV (share of cash-on-hand)

Figure 12: Welfare consequences of altering the required down payment
Note: (a) Mean CV for different down-payment requirements. (b) Mean CV, expressed as share of cash-on-hand, across income deciles; comparing the baseline economy to a setting with a 20 percent down-payment constraint.

vary across income, when comparing the baseline economy to a setting with a 20 percent down-payment constraint. For ease of comparison, we express the CV as a fraction of households' cash-on-hand rather than absolute amounts. Quite strikingly, the households who are worst affected by the policy are those with high levels of income. For the decile with the highest income, the welfare loss is equivalent to approximately 10 percent of cash-on-hand. In contrast, the households with the lowest income barely lose at all.

There are three primary factors contributing to high-income households being disproportionately worse affected by stricter down-payment constraints. First, only those who buy a house at some point in their life are directly affected by the policy. Households who start life with low earnings are more likely to have low earnings later in life, which in turn makes them less likely to ever become a homeowner. Second, and relatedly, households with high earnings tend to buy a house relatively early in life. An increase in the down-payment requirement therefore affects them at a point in their life where earnings are relatively low and quickly increasing. As a result, the stricter constraint makes them save more to buy a home when this is relatively costly in utility terms, as compared to low-income households who tend to purchase a house closer to the peak of the income profile. High-earning households therefore adjust their saving behavior more in response to a stricter policy. They postpone their house purchase more than low-earning households do, and they respond more in terms of choosing smaller houses. Lastly, since a larger down-payment requirement affects high-earners earlier in life, their welfare losses are discounted for fewer periods, than the losses of low-earners.

6 Conclusions

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

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

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Online Appendix

A Simple models in discrete time

We first study a two-period 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 discrete-time life-cycle setting to capture how changes in the down-payment constraint affect saving dynamics.

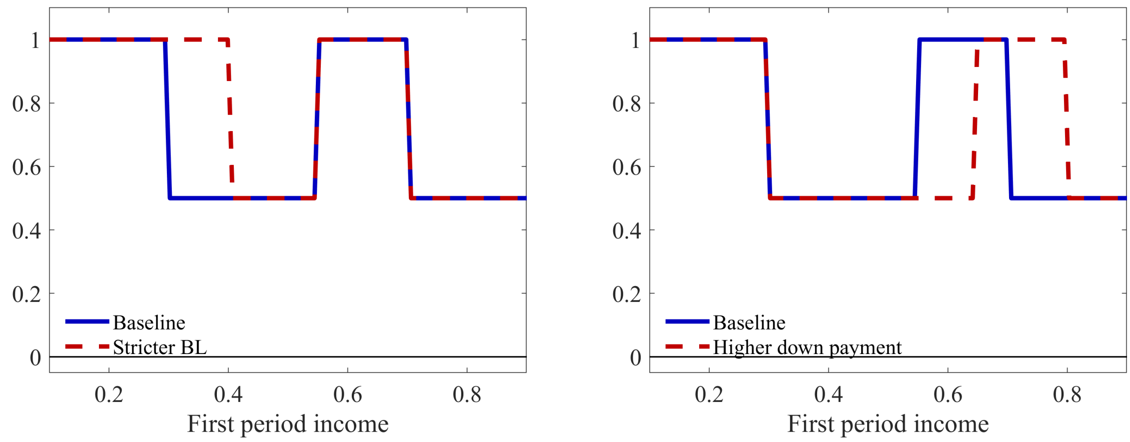
A.1 A two-period model

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

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

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

The solid line in Figure 13 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 poor 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 saving, 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 $\bar{b}$, are unconstrained and have an MPC of 0.5.



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

Figure 13: 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 13a 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 13b illustrates households' MPC when we instead increase the down-payment requirement. In contrast to the case of a stricter borrowing constraint, the mean MPC can increase *or* decrease in response to a stricter down-payment requirement. On the one hand, some households no longer find it worthwhile to save the amount required to obtain the utility bonus, as it means lowering first-period consumption even further. Instead, they choose to become renters to better smooth consumption across the two periods. This reduces their MPC. On the other hand, some previously unconstrained homeowners are now limited by the tougher requirement. These households previously saved more than the old down-payment constraint, but in order to comply with the new requirement they have to increase their savings. This increases their MPC. Overall, the stricter down-payment requirement causes a shift in the composition of wealthy HtM households towards households with higher income. Consequently, the effect on the average MPC depends on the income distribution in the economy.

A.2 A life-cycle model in discrete time

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, as shown in Section 2, changes to the down-payment constraint affect the timing of house purchases and saving dynamics. To further support this claim, and to bridge the gap between the continuous-time model in Section 2 and the quantitative model in Section 3, this section studies a simple life-cycle model in discrete time.

The model in this section is a discrete-time version of the model in Section 2. The only difference from the model in Section 2 is that we now consider a specific income profile that also includes a retirement phase. This is included to capture a life-cycle saving motive, which incentivizes homeowners to potentially save beyond the down payment. The model is a stylized life-cycle model with one representative household per age j. Households are born at age 23, work until age 64, and die with certainty at age 83. Households face an upward-sloping earnings profile, and receive benefits during retirement. The age-dependent income is the only source of heterogeneity in the model. For simplicity, and to roughly mimic a typical earnings profile from the data, we assume that earnings grow linearly and are doubled during working age. The replacement rate during retirement is set to one half of earnings in the period before retirement, and the mean income is normalized to one.

First, consider the model from Section 2 but formulated in discrete time, where the choice of total savings today is denoted by a', and x is the state variable cash-on-hand.

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

Second, we change the notation so that we are consistent with the quantitative model in Section 3. We start by introducing the notion of housing, although the underlying model remains unchanged. Total savings are then made up by savings in liquid bonds b or housing h, such that, $a' \equiv b' + h'$. We assume that housing is a binary choice, which gives the household two possibilities: either it chooses $h' = 0$, and receives no utility bonus, which represents renting, or it chooses $h' = \bar{h}$, which represents owning and gives the bonus, but forces the household to save up at least $b' = \theta\bar{h}$, where θ is the required down payment as a share of the house value. The households' dynamic problem is isomorphic to the above setup, and is characterized by

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

In each period, households choose consumption c, savings in risk-free liquid bonds b', and housing h', subject to the traditional borrowing limit and the down-payment requirement. Similarly to the model in Section 2, we assume that households do not discount the future ($\beta = 1$), the interest rate on savings in risk-free bonds is zero ($r = 0$), and we also assume that households have log preferences over consumption.

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

The importance of the two constraints varies over the life cycle, as illustrated by the solid lines in Figure 14a, 14b, and 14c, which depict the life-cycle profiles of net worth, consumption, and MPCs in our baseline parameterization. For young households, with relatively low income, the traditional borrowing limit is binding. They save nothing and consume all that they earn, resulting in a HtM behavior and an MPC of 1.

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

Once the savings reach the required down payment, households become homeowners, and any further savings are driven by the desire to save for retirement. Since the households have already saved a substantial amount to become homeowners, they do not increase savings further for some time and instead consume all their income. Therefore, despite having positive wealth, these homeowners have an MPC of 1 and are classified as wealthy HtM households.[27] As earnings continue to increase, households' optimal savings eventually exceed the down-payment requirement, and they become unconstrained owners.[28]

The dashed lines in Figure 14a, 14b, and 14c illustrate how the life-cycle patterns of savings, consumption, and MPCs change when the down-payment constraint is made stricter. In line with the analysis in Section 2, households delay saving for the down payment and become homeowners at a later point in life when the required down payment is larger. Notably, although a higher down-payment constraint requires households to save more to become homeowners, young households still choose to save less, which results in an increase in the share of poor HtM households. Moreover, as households postpone homeownership, the share of wealthy HtM households decreases as there are fewer young homeowners and the time it takes for homeowners' optimal savings for retirement to exceed the down payment is shorter.

Figure 14d demonstrates the effects of a wide range of down-payment constraints on

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

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

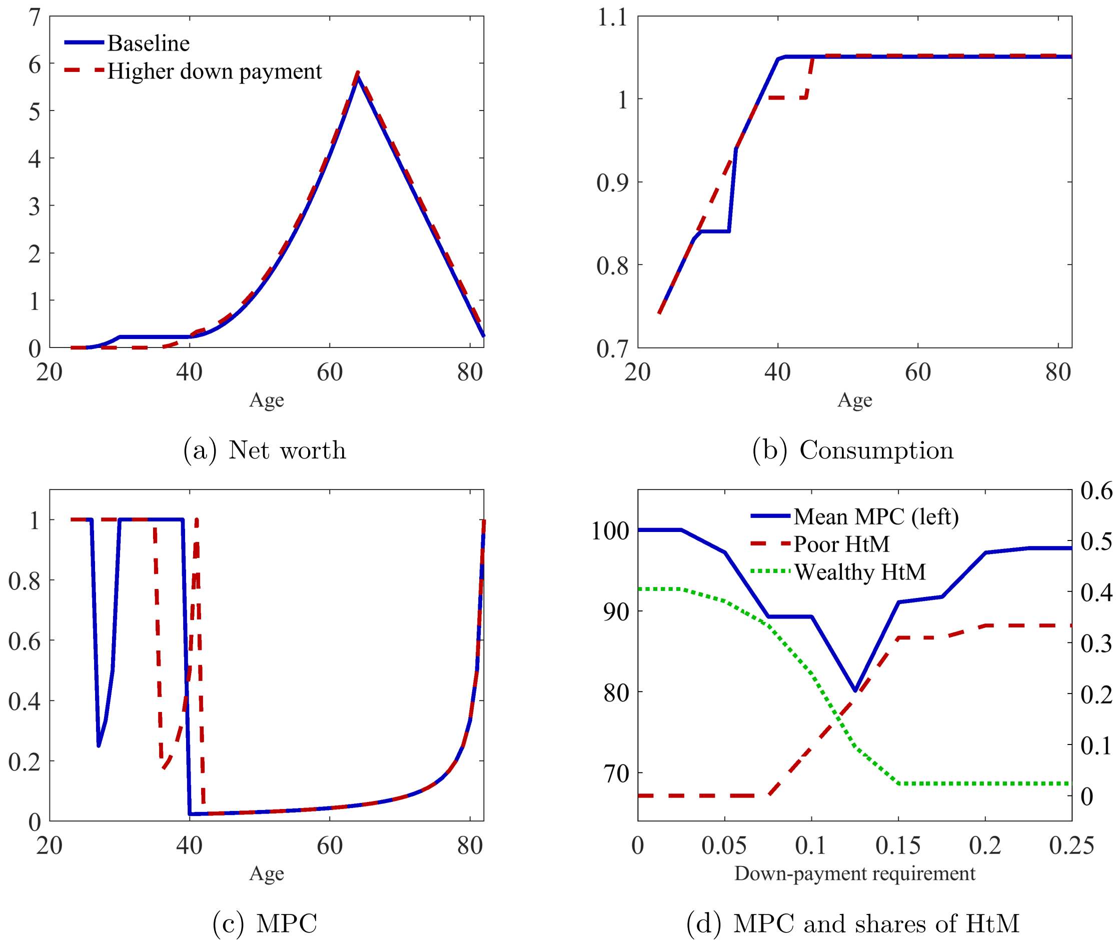


Figure 14: Life-cycle profiles in a stylized model, and mean MPC and shares of wealthy and poor hand-to-mouth households across a range of down-payment requirements.

the mean MPC in the economy and the shares of poor and wealthy HtM households. A key finding from this figure is the U-shaped relationship between the mean MPC and the down-payment constraint.

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

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

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

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

B Additional analysis of the continuous-time model

B.1 Necessary conditions for the existence of an interior solution

Let us examine equation (8) further. Recall that $g(\hat{t})$ is the marginal benefit from delaying saving. As noted before, the sign of $g'(\hat{t})$, and thereby the slope of the marginal benefit curve in Figure 2b and 3b, is determined by two factors: the functional form of the utility function and the shape of the income profile.

Regarding the utility function, since it is concave, the marginal benefit of delaying saving is lower the higher the household's consumption is at the time it starts to save. Since the income profile is upward sloping, consumption at $\hat{t}$ is an increasing function of $\hat{t}$. Therefore, the concavity of the utility function contributes to the marginal benefit being a decreasing function of $\hat{t}$, i.e. $g'(\hat{t}) < 0$.

Turning to the shape of the income profile, the key is to understand that the marginal change in the level of consumption as a function of $\hat{t}$ inherits the shape of the income profile, since $c_t = y_{\hat{t}}$ during the periods in which the household saves. To clarify it is useful to examine three cases. First, with concave income, the higher is $\hat{t}$, the smaller is the increase in consumption from further delaying the time to start saving. In other words, the marginal benefit of delaying saving is lower for higher $\hat{t}$, which contributes to the marginal benefit curve being downward sloping. Second, with a linear income profile, a marginal delay in saving has the same impact on consumption regardless of when the household starts to save. Finally, with convex income, a marginal delay in saving has a larger impact on consumption the higher $\hat{t}$ is. This implies that the marginal benefit from a marginal postponement of saving is increasing in $\hat{t}$. In isolation, this positive relationship implies that the marginal benefit curve is an increasing function of $\hat{t}$. Hence, if income is sufficiently convex, this effect might outweigh the effect stemming from the concavity of the utility function. If that is the case, the slope of $g(\hat{t})$ becomes positive instead of negative.

However, in the case where $g'(\hat{t}) > 0$, the function $\tilde{V}(\hat{t})$ is locally convex, i.e., $\tilde{V}''(\hat{t}) > 0$, at the extreme point that satisfies the first-order condition. This means that equation (6) pins down a local minimum rather than a maximum, and consequently it is not a solution to the household's problem. We conclude that the necessary conditions for the existence of an interior solution to the household's maximization problem, as characterized by equation (6), are as follows. First, the utility function is concave. Second, the income profile is increasing in age, and is linear, concave, or convex, as long as the convexity is not "too strong" relative to the concavity of the utility function. Moreover, the monotonicity of $g(\hat{t})$ also implies a single crossing point, meaning that the interior solution is unique.

B.2 The case of exponentially increasing earnings

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

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

where g^y determines the growth rate of income. First, solve the integral in equation (1) and rewrite to get

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

Next, rewrite the equilibrium condition in equation (6) and use it to substitute the first term on the right-hand side of the equation. The equation then simplifies to

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

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

$$\hat{t} = \frac{1}{g^y} \log \left(\frac{g^y \bar{b}}{\Psi} \right). \tag{25}$$

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

$$\frac{d\hat{t}}{d\bar{b}} = \frac{1}{g^y \bar{b}}, \tag{26}$$

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

B.3 Step-by-step calculations

Equation (2):
By applying Leibniz' integral rule to equation (1), we get

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

where $\dot{y}_{\hat{t}} \equiv \frac{dy_{\hat{t}}}{d\hat{t}}$. For a given down payment, the left-hand side is zero. Hence, we have

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

Equation (5):
Taking the derivative of equation (4), using Leibniz' integral rule on the second term, yields

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

Note that the second term in the brackets is zero. Then, the expression can be written as

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

Re-arrange to obtain equation (5)

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

Equation (6):

Using equation (2), we can re-write the first term on the right-hand side of equation (5) and obtain

$$\Psi \frac{d\bar{t}}{d\hat{t}} = u'(y_{\hat{t}})(y_{\bar{t}} - y_{\hat{t}})\frac{d\bar{t}}{d\hat{t}} - (u(y_{\bar{t}}) - u(y_{\hat{t}}))\,\frac{d\bar{t}}{d\hat{t}}.$$

Cancel out $d\bar{t}/d\hat{t}$ to obtain

$$\Psi = u'(y_{\hat{t}})(y_{\bar{t}} - y_{\hat{t}}) + u(y_{\hat{t}}) - u(y_{\bar{t}}),$$

where the right-hand side is $g(\hat{t})$.

Equation (7):
When considering a change in $\bar{b}$ while keeping $\hat{t}$ fixed, note that $\bar{t}$ is a function of $\bar{b}$ as a larger down payment means that the household has to save for a longer time. Therefore, the partial derivative of the right-hand side of equation (6) is

$$\frac{\partial g}{\partial \bar{b}} = u'(y_{\hat{t}})\dot{y}_{\bar{t}}\frac{\partial \bar{t}}{\partial \bar{b}} - u'(y_{\bar{t}})\dot{y}_{\bar{t}}\frac{\partial \bar{t}}{\partial \bar{b}}.$$

Collect terms to obtain equation (7)

$$\frac{\partial g}{\partial \bar{b}} = (u'(y_{\hat{t}}) - u'(y_{\bar{t}}))\dot{y}_{\bar{t}}\frac{\partial \bar{t}}{\partial \bar{b}}.$$

Equation (8):
We have

$$g(\hat{t}) = u(y_{\hat{t}}) - u(y_{\bar{t}}) + u'(y_{\hat{t}})(y_{\bar{t}} - y_{\hat{t}}).$$

The derivative is

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

We are interested in the condition $g'(\hat{t}) < 0$. This is satisfied when

$$
\begin{aligned}
\left(u'(y_{\hat{t}}) - u'(y_{\bar{t}})\right) \dot{y}_{\bar{t}} \frac{\dot{y}_{\hat{t}}(\bar{t}-\hat{t})}{y_{\bar{t}} - y_{\hat{t}}} + u''(y_{\hat{t}})\dot{y}_{\hat{t}}(y_{\bar{t}} - y_{\hat{t}}) < 0 \\
u''(y_{\hat{t}})\dot{y}_{\hat{t}}(y_{\bar{t}} - y_{\hat{t}}) < \left(u'(y_{\bar{t}}) - u'(y_{\hat{t}})\right) \dot{y}_{\bar{t}} \frac{\dot{y}_{\hat{t}}(\bar{t}-\hat{t})}{y_{\bar{t}} - y_{\hat{t}}} \\
u''(y_{\hat{t}})(y_{\bar{t}} - y_{\hat{t}}) < \frac{u'(y_{\bar{t}}) - u'(y_{\hat{t}})}{y_{\bar{t}} - y_{\hat{t}}} \dot{y}_{\bar{t}}(\bar{t}-\hat{t}).
\end{aligned}
$$

Re-arranging the expression slightly, noting that $u'(y_{\bar{t}}) - u'(y_{\hat{t}}) < 0$, yields

$$
\frac{u''(y_{\hat{t}})}{\frac{u'(y_{\bar{t}}) - u'(y_{\hat{t}})}{y_{\bar{t}} - y_{\hat{t}}}} > \frac{\dot{y}_{\bar{t}}}{\frac{y_{\bar{t}} - y_{\hat{t}}}{\bar{t}-\hat{t}}}.
$$

C Definitions of stationary equilibrium

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

Stationary equilibrium, exogenous prices

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

1. Given the prices $(p_h = 1, p_r)$, $V_j(\mathbf{u})$ solves the Bellman equation (20) 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 (21).

3. The quantity of the total housing stock is given by the total demand for housing

services[29]

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

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

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

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

Stationary equilibrium, endogenous prices

Definition 2. A stationary recursive competitive equilibrium after a permanent policy change is a collection of value functions $V_j(\mathbf{u})$ with associated policy functions $\{c_j(\mathbf{u}), s_j(\mathbf{u}), h'_j(\mathbf{u}), m'_j(\mathbf{u}), b'_j(\mathbf{u})\}$ for all j; prices (p_h, p_r); a quantity of total housing stock H; and a distribution of agents' states Φ_j for all j such that:

1. Given prices (p_h, p_r), $V_j(\mathbf{u})$ solves the Bellman equation (20) 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 (21).

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 $j < J$

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

D 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

[29] 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.

method G^{2}EGM by Druedahl and Jørgensen (2017) to solve for the value and policy functions. The number of grid points for permanent earnings N_Z, cash-on-hand N_X, housing sizes N_H, bonds-over-earnings N_B, and loan-to-value N_{LTV}, are 9, 70, 15, 25, and 31, 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.

E Labor income process

E.1 Data sample

Equation (9) 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).

E.2 Estimation

In this section, we describe how the exogenous earnings process in equation (9) is estimated. First, we estimate the deterministic life-cycle earnings profile $g(j)$, and then we move on to the variances of the fixed-effect component σ^2_α, the permanent shock σ^2_η, and the transitory shock σ^2_ν.

To estimate the deterministic age-dependent earnings component $g(j)$, we use yearly observations in the data for ages 20 to 64. Log household earnings $\log(y_i)$ are regressed on dummies for age (not including the youngest age), marital status, family composition (number of family members besides head and, potentially, wife), and a dummy for whether the household head has a college education. Household fixed effects are controlled for by running a linear fixed-effect regression. Finally, a third-order polynomial is fitted to the predicted values of this regression, which provides us with the estimate of the deterministic life-cycle earnings profile $\hat{g}(j)$.

We follow Carroll and Samwick (1997) when we estimate the variances of the transitory (σ^2_ν) and permanent (σ^2_η) shocks. Define $\log(y^*_{ij})$ as the 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 (9). Define r_{id} as household i's d-period difference in $\log(y^*_{ij})$,

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

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

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

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

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

F Additional results

F.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 15 shows the mean house size (quality) among those who own in both the baseline setting and in the economy with a down-payment constraint of 40 percent. Most attention should be paid to ages above 35, since there are almost no homeowners younger than 35 when the required down payment is 40 percent, as illustrated in Figure 6b. 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.

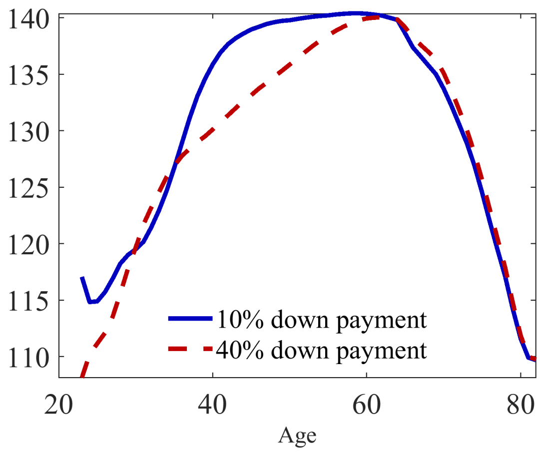


Figure 15: Mean house size (quality) conditional on owning in both equilibria, over the life cycle

F.2 Fixed housing supply

The results in Section 5 are 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 is perfectly elastic in the long run, which we believe is a relevant assumption for many housing markets. However, for robustness, we make the opposite assumption in this section. We let the supply of housing be perfectly inelastic, and solve for the house price that clears the housing market.[30] We solve the model under a wide range of down-payment requirements and compare our results to those under perfectly elastic housing supply.

Figure 16 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 9d. The reason behind this result is that the change in down payment only has a modest effect on house prices (see also the discussion in Kaplan et al. (2020)). The stricter lending standards push households out of ownership and into renting. However, this is a change in the tenure status of households and there are only small effects on the quantity of housing demanded. Thus, the equilibrium prices do not change much. As a result, the effects of stricter down-payment constraints on households' choices and their MPCs, are similar under the different assumptions on the housing-supply elasticity.

[30]A change in the house price affects the value of bequests. We account for this by deflating the net worth q' in the utility function for bequests by the price index $1 - \alpha + \alpha p_h$.

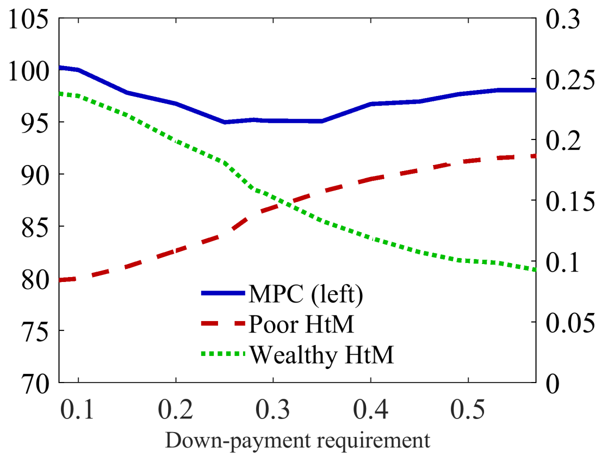


Figure 16: Mean MPC (percent of baseline) and shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, under the assumption of perfectly inelastic housing supply

F.3 Varying the shock size

In the core analysis of the paper we focus on the consumption responses to a negative income shock. However, the size and sign of the shock is set somewhat arbitrarily. For this reason, this section explores to what extent our results concerning households' MPCs depend on the size and sign of the exogenous income shock.

Figure 17 displays the mean MPC across different down-payment constraints, where the shock is varied from negative 4 000 dollars to positive 10 000 dollars. The second highest line, corresponding to the negative shock of 1 000 dollars, is the same as in Figure 9d. Two things can be noted. First, there is a clear negative relationship between the size of the shock and the mean MPC. This is reasonable, as a negative shock pushes households closer to the credit constraints, whereas a positive shock moves the households away from the constraints. Quantitatively, this relationship is not large, but also not entirely insignificant. For the largest negative shock the average MPC is just below 0.2 when the down-payment constraint is 10 percent. When we instead consider a positive shock of 10 000 dollars, the mean MPC falls to just below 0.18. Second, we see that the U-shaped relationship between the down-payment requirement and the mean MPC is relatively robust.

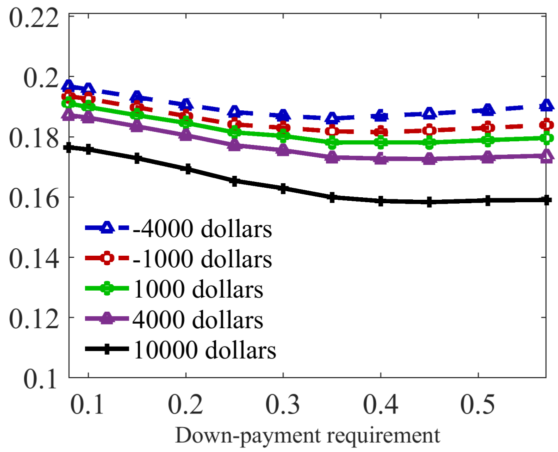
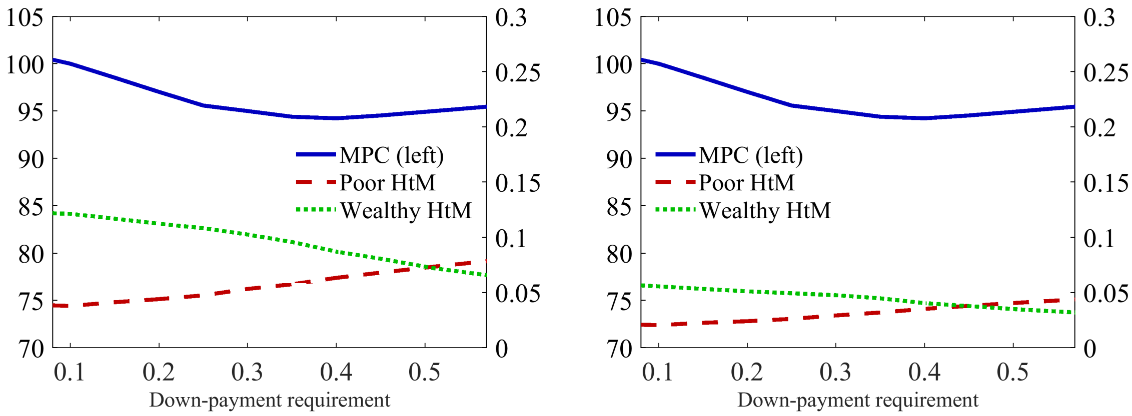


Figure 17: Mean MPC across various down-payment requirements for positive and negative shocks of different sizes

F.4 Alternative definitions of hand-to-mouth

In Section 5, we label a household with an MPC greater than 0.3 as a HtM household. As this threshold is somewhat arbitrary, we here explore the robustness of our findings with respect to the definition of hand-to-mouth. Figure 18a and 18b 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 saving for the house and delay the purchase, resulting in more poor HtM and fewer wealthy HtM households. The mean MPC is of course not affected by the definition of HtM.



(a) Defining HtM as MPC> 0.5 (b) Defining HtM as MPC> 0.7

Figure 18: Mean MPC (percent of baseline) and shares of wealthy and poor hand-to-mouth households, across various down-payment requirements

F.5 Lowering transitory risk

Households with high MPCs typically have 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

$$\sigma_\eta^2 = \frac{\sigma_y^2(J_{ret}) - \sigma_y^2(1)}{J_{ret} - 1} \tag{27}$$
$$\sigma_\alpha^2 = \sigma_y^2(1) - \sigma_\eta^2 - \sigma_\upsilon^2. \tag{28}$$

The estimated variances are presented in Table 4.

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

Table 4: Estimated variances of earnings shocks, assuming lower transitory risk
Note: Household earnings contain a fixed household component. Throughout working life, earnings are subject to permanent and transitory shocks, while in retirement there is only transitory earnings risk.

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

Figure 19 illustrates the relationship between the required down payment and the mean MPC and the shares of HtM households. The results are qualitatively similar to the baseline model, but quantitatively stronger. The reason is that less transitory risk lowers the precautionary saving motive, meaning there are more constrained households that are

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

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

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

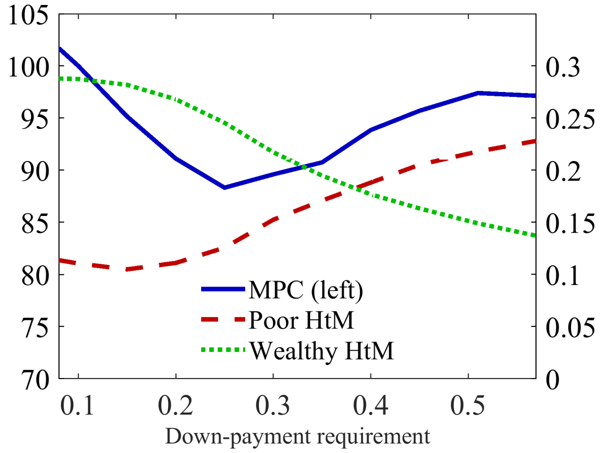


Figure 19: Mean MPC (percent of baseline) and shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, in a setting with less transitory income risk

affected by the policy change. The mean MPC is again U-shaped, but the minimum is achieved at a somewhat smaller down-payment constraint than in the baseline calibration. The reduction in the mean MPC is over 10 percent at the minimum, as opposed to 5 percent in the baseline.

F.6 Soft down-payment constraint

Since there is no formal down-payment constraint currently in place in the U.S., we here analyze how robust our findings are with respect to this aspect.[31] We do so by introducing a soft down-payment constraint of 20 percent, which is the threshold for which a mortgage

[31] We have also run the same analysis as in the main paper using a comparable quantitative model calibrated to Norway, which is a country that has a formal down-payment constraint. Our results are qualitatively unchanged. This analysis is available upon request.

insurance is required in the U.S. A household that takes up a mortgage and has less equity in the house than this threshold has to pay a one-time fee. We set this fee to 3 percent of the mortgage size, broadly in line with the initial insurance costs of Federal Housing Administration (FHA) loans. The new calibration is shown in Table 6 and the main results are displayed in Figure 20.

Parameter	Description	Value	Target moment	Data	Model
α	Consumption weight in utility	0.762	Median house value-to-earnings, age 23–64	2.29	2.26
β	Discount factor	0.950	Mean net worth, over mean earnings age 23–64	1.40	1.44
υ	Strength of bequest motive	4	Mean net worth age 75 over mean net worth age 50	1.67	1.56
Ψ	Utility bonus of owning	0.3	Mean own-to-rent size	1.80	1.75
δ^r	Depreciation rate, rentals	0.058	Homeownership rate, age 30–40	0.58	0.55
$\underline{h}$	Minimum owned house size	173	Homeownership rate, all ages	0.67	0.68
ς^r	Refinancing cost	2.53	Refinancing share, homeowners	0.08	0.08
λ	Level parameter, tax system	1.698	Average marginal tax rates	0.13	0.13
τ^p	Progressivity parameter	0.142	Distribution of marginal tax rates	N.A.	N.A.

Table 6: Internally calibrated parameters, with a soft down-payment constraint

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

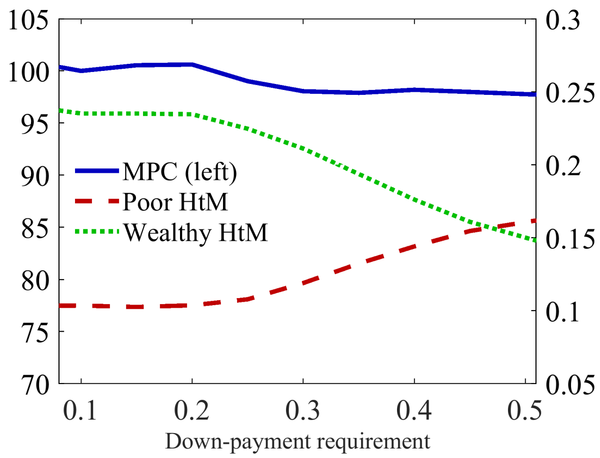


Figure 20: Mean MPC (percent of baseline) and shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, including a soft down-payment constraint of 20 percent. Having less housing equity than this threshold, when taking up a new mortgage, requires an additional insurance that costs 3 percent of the mortgage, upfront.

When having a soft down-payment constraint of 20 percent in place, there is less of a change when increasing the formal constraint from 10 percent to 20 percent. This is apparent in the figure, where the shares of poor and wealthy HtM and the mean MPC are hardly affected up until a constraint of 20 percent. However, for stricter levels of the formal down-payment requirement the main findings of the paper still hold. When the constraint is stricter, there is a delay in when households start saving for a house, and they end up buying a house later. As a result, the number of poor HtM households increases and the number of wealthy HtM declines. The effect on the average MPC is even more muted than in the baseline analysis.

F.7 Increasing the baseline down-payment constraint

In our baseline calibration of the model, 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 7.

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

Table 7: Internally calibrated parameters, under a higher baseline down-payment constraint
Note: Parameters calibrated to match model moments to their counterparts in the data. The first two columns list the parameters and their descriptions. The third column shows the calibrated parameter values. The fourth column contains the descriptions of the targeted moments, while column five lists their respective values in the data. Finally, the last column states the values of the corresponding model moments, achieved by using the parameter values in column three. The minimum owned house size $\underline{\mathrm{h}}$ and the fixed refinancing cost ς^r are in 1000's of 2019 dollars.

The main results are summarized in Figure 21. The alternative calibration does not materially change our findings. When the down-payment constraint is stricter, households delay saving for the house and postpone the purchase, resulting in more poor HtM households and fewer wealthy HtM. The mean MPC is again U-shaped in the required down payment. The minimum is achieved at a down-payment constraint of approximately 40 percent, but this is consistent with a reduction of mean MPC of roughly 7 percent from its current level, which is somewhat larger than the 5 percent reduction in the main analysis.

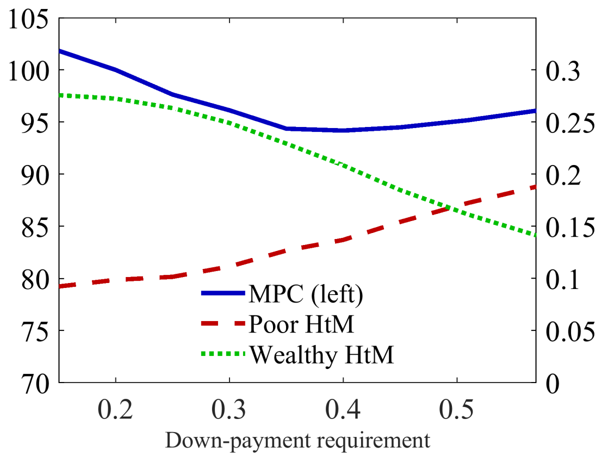


Figure 21: Mean MPC (percent of baseline) and shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, setting $\theta = 0.2$ in the baseline calibration

F.8 Lowering the refinancing cost

The decision to hold precautionary savings in the liquid asset depends not only on the degree and type of risk that the household faces, but also on how illiquid the alternative asset is. In this setting, the alternative to using bonds to cushion negative income shocks is to use housing equity by cash-out refinancing. Therefore, it is of interest to study how the main conclusions of the paper depend on how illiquid housing equity is. To do this, we re-do the main exercise of the paper for an alternative calibration where the refinancing cost is halved. The model is then recalibrated to match the same moments as before, except that the share of households who refinance in every period is left untargeted. The calibration is summarized in Table 8, and the main results are illustrated in Figure 22. The results are largely unchanged.

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

Table 8: Internally calibrated parameters, under a lower refinancing cost

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 $\underline{h}$ is in 1000's of 2019 dollars.

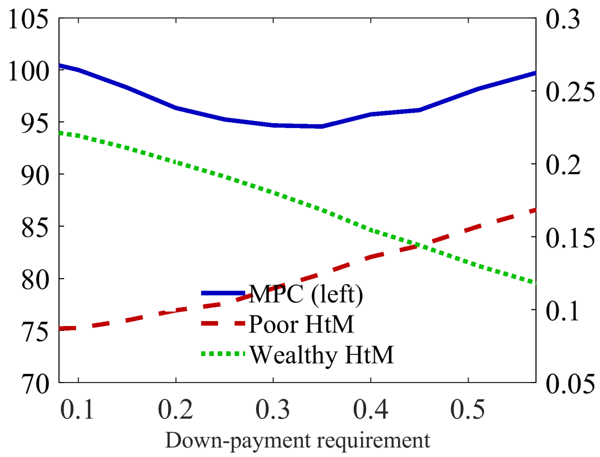


Figure 22: Mean MPC (percent of baseline) and shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, setting the refinancing cost to half that of the baseline calibration

F.9 Lowering the calibrated PTI requirement

While the paper focuses exclusively on changes to the down-payment requirement, the model also features another constraint in the mortgage market: the payment-to-income requirement. This section looks at how the tightness of the PTI requirement interacts with the results of the paper. We do this by lowering the PTI requirement by ten percent, from $\phi = 0.177$ to $\phi = 0.1593$. The model is then recalibrated to match the same moments as before. The calibration is summarized in Table 9, and the main results are illustrated in Figure 23.

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

Table 9: Internally calibrated parameters, under a stricter PTI constraint

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

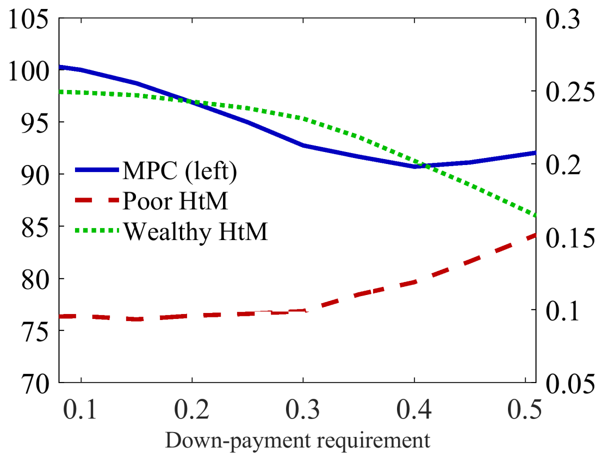


Figure 23: Mean MPC (percent of baseline) and shares of wealthy and poor hand-to-mouth households, across various down-payment requirements, assuming a 10 percent lower PTI constraint than in the main analysis

The qualitative conclusions of the paper still hold. The mean MPC is U-shaped in the down-payment constraint, and the minimum is achieved around a constraint of 0.4. The main difference from the baseline calibration is that the shares of poor- and wealthy HtM agents are not as affected by changes in the down-payment requirement, especially at low levels of the constraint. The reason is that with a stricter PTI requirement, the down-payment requirement is less likely to be the binding constraint. Therefore, the effect is weaker, initially. However, once we look at a situation where the required down payment is 25 percent of the house value or more, changes to the constraint again affect who is constrained.

F.10 A proportional income shock

In the paper, we analyze how changes to the down-payment requirement affect the distribution of MPCs, and what this implies for, e.g., the mean MPC. It may also be relevant to consider shocks to cash-on-hand that are unevenly distributed across households with different income. Here, we therefore study the aggregate consumption response to an unexpected transitory income shock that is proportional to current income. Specifically, we consider a one percent decrease in earnings for all working-age households, and examine how the aggregate consumption response depends on the level of the down-payment constraint.

In Figure 24, we see that a stricter down-payment requirement leads to a smaller consumption response. The effect is fairly large, with roughly a 10 percent reduction in the response when the down-payment constraint is 35 percent as compared to the baseline. The change in the response is more than twice as large as compared to how the mean MPC is affected, which captures the aggregate response when all household are hit by a shock of the same absolute size. The underlying reason is that the MPCs of high-earning households are the most affected by a stricter down-payment constraint; and their MPCs decrease. Since they experience the largest shock in absolute terms in this scenario, they drive the aggregate response.

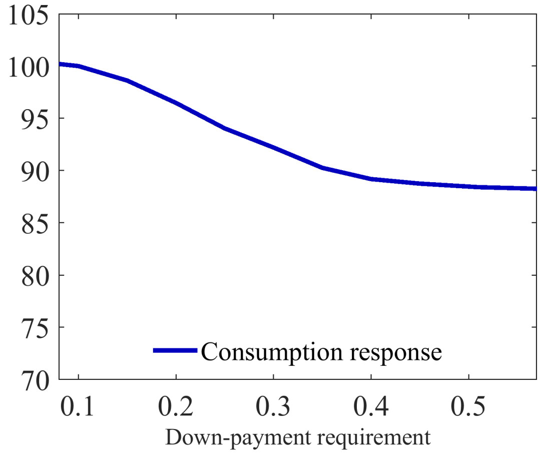


Figure 24: The aggregate consumption response to a 1 percent shock to households' earnings. The response is normalized to 100 for the economy with a 10 percent down-payment requirement.