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Housing, Mortgages, and Self-Control

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Using a quantitative theoretical framework this paper analyzes how problems of self-control influence housing and mortgage decisions. The results show that people with stronger problems of self-control are less likely to become homeowners, even though houses serve as commitment for saving. The paper then investigates the welfare effects of regulating mortgage products if people differ in their degree of self-control. Holding house prices fixed, higher down payment requirements and restrictions on refinancing turn out to be beneficial to people with sufficiently strong problems of self-control, even though these policies restrict access to the commitment device. (*JEL* D15, D91, E21)

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Since the recent crisis in the housing and mortgage market, regulators across the globe have been assessing the usefulness and dangers of mortgage products. For example, both in the United States and in the United Kingdom regulators recently issued rules that limit the use of mortgage types that are deemed to harm consumers' welfare (Consumer Financial Protection Bureau, 2013, Financial Services Authority, 2012). However, to assess if certain aspects of mortgage products are harmful to consumers' welfare, it is necessary to understand what determines housing and mortgage decisions. In this context, regulators are particularly worried that consumers might not behave fully rationally. For instance, Martin Wheatley, the first head of the Financial Conduct Authority in the United Kingdom, stated that he wants to "adapt our regulation

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to their [the consumers'] behavioral traits" (Wheatley, 2012). In the United States Oren Bar-Gill and Elizabeth Warren argued for the creation of an agency that later became the Consumer Financial Protection Bureau by stating that "consumers, their families, their neighbors, and their communities are paying a high price for systematic cognitive errors.... To restore efficiency to consumer credit markets...basic safety regulation is needed" (Bar-Gill and Warren, 2008). The purpose of this paper is to formalize these concerns by investigating in a quantitative theoretical analysis how lack of self-control, a form of limited rationality extensively studied in other contexts, influences housing and mortgage decisions of consumers and how regulation of mortgage products affects the welfare of people with different degrees of self-control. By doing so, the paper contributes to the literature of household finance (see, e.g., the presidential address by Campbell [2006]) and to how consumer financial protection can change consumer welfare (see, e.g., Campbell et al. [2011]).

Problems of self-control are particularly interesting in the context of housing and mortgages because buying a house and taking out a mortgage can serve as commitment for saving. Houses are an illiquid investment and mortgages require continuous payments, so both assets can alleviate problems of self-control. At the same time, however, purchasing a house requires making a down payment, and saving for this down payment is more difficult for people with low degrees of self-control. The results I obtain show that the latter effect dominates: households with problems of self-control are up to 17 percentage points less likely to be homeowners. This indicates that even though houses serve as commitment for saving, exactly the people who need the commitment device the most are the ones who are the least likely to make use of it. Moreover, if they become homeowners, the value of their houses is up to US$5,000 lower and their loan-to-value ratios are up to 21 percentage points higher.

These results are obtained by analyzing how problems of self-control affect housing and mortgage decisions in a quantitative life-cycle model. Agents face uninsurable, idiosyncratic income risk, as in Deaton [1991] and Carroll [1997], which makes the investment in a house risky since it is only partly reversible. Problems of self-control are modeled by assuming that households have Dynamic Self-Control Preferences (Gul and Pesendorfer, 2001, 2004) in the sense that they are always tempted to maximize their current utility instead of their expected lifetime utility. The model is set in partial equilibrium where house prices are exogenous but the mortgage market clears: mortgage pricing by competitive lenders reflects the default risk of borrowers, taking their whole portfolio of income, housing, home equity lines of credit (HELOCs), and liquid savings and unsecured borrowing through credit card debt into account. It is calibrated to the U.S. economy allowing for heterogeneity in the degree of self-control.

The effects of self-control on housing and mortgage decisions are the result of two opposing effects. On the one hand, people with problems of self-control find it harder to give up consumption because this would lead to current costs of self-control. This is the *impatience effect*. It makes current consumption more important relative to future consumption. Accumulating enough wealth for the down payment of a house is thus more costly. On the other hand, people with costs of self-control also take into account that their current actions affect the temptation that they will face in the future and hence their future costs of self-control. This *anticipation effect* thus generates a desire for commitment. Houses can be such a commitment device since home equity is an illiquid form of investment. People with costs of self-control are thus not tempted to spend this part of their savings, which reduces their costs of self-control. In the calibrated model, I show that both effects are important for the housing and mortgage decision. Overall, however, the quantitative results reveal that the impatience effect dominates the anticipation effect.

The model is used to analyze the welfare consequences of financial regulation in the mortgage market. For a standard consumer, policies that restrict his choice set are always weakly welfare reducing. However, if people have costs of self-control, these policies not only restrict their actual behavior but also change the temptation that they face each period. I show that welfare benefits from reducing temptation can overcome the welfare loss of having to alter one's behavior. Agents with costs of self-control can hence benefit from policies that would reduce the welfare of people without costs of self-control. To assess the consequences of financial regulation, it is therefore important to take the costs of self-control into account.

The paper looks at two specific policy experiments: first, I show that in this partial equilibrium framework a substantial down payment requirement of 20% would be beneficial to people with problems of self-control. This is true even though it makes it harder to purchase a house and hence to get access to the commitment device. Increasing the minimum down payment requirement forces households to pay a higher share of the purchase price up-front in the period in which they buy a house. For people without costs of self-control, this is the only effect, and they can therefore never be better off with this policy. For people with costs of self-control, however, there is a second effect. If the minimum down payment requirement is very low, then they are tempted to buy a large house by taking out a large mortgage. Exercising self-control to resist this temptation is costly. Increasing the minimum down payment hence reduces the temptation the agents face each time they consider buying a house. Moreover, for homeowners it also reduces the amount of home equity that can be extracted through HELOCs or refinancing. This strengthens the commitment aspect of the house. In the calibrated model, the reduction in temptation outweighs the negative effect of making a house purchase more difficult. Agents with costs of self-control are hence better off if subprime mortgages with low down payment requirements are not available.

Second, the paper shows that the option to prepay and hence to refinance a mortgage can lower the welfare for people with problems of self-control. This is in contrast to people without problems of self-control, who are unambiguously better off if refinancing is possible. For all households the possibility to refinance their mortgage implies that they can more easily adjust their leverage position and use their home equity to smooth income shocks. However, the fact that people can easily access their home equity reduces the commitment value of the house since people are tempted to extract home equity for current consumption. In the calibrated model, the increase in temptation outweighs the gain of flexibility for people with problems of self-control. In this partial equilibrium framework, they would hence be better off if refinancing were restricted. Furthermore, the welfare gain is higher for wealthier households since they are more likely to be homeowners and therefore benefit more if houses offer stronger commitment.

The two considered policy experiments are not only interesting because they affect the commitment character of houses and mortgages in the context of problems of self-control. They are also interesting because both minimum down payment requirements and the regulation of prepayment penalties have been in the discussion of policy measures in the aftermath of the financial crisis. For example, the Financial Services Authority in the United Kingdom debated the introduction of maximum LTV requirements in their Mortgage Market Review but decided not to implement them for the time being (Financial Services Authority, 2011, Edmonds, 2014). In the United States, prepayment penalties have been severely restricted (Consumer Financial Protection Bureau, 2013). This is in contrast to most other developed countries, where prepayment penalties are typically high (Green and Wachter, 2005). The current paper shows how problems of self-control affect the consequences of these forms of regulation.

The present paper is related to the literature in two areas. First, it is related to papers on housing and mortgages in the context of household finance. This area has been the subject of great interest since the crisis in the housing and mortgage market. Quantitative theoretical studies that focus on life-cycle considerations include Chambers, Garriga, and Schlagenhauf [2009], Attanasio et al. [2012], Iacoviello and Pavan [2013], and Campbell and Cocco [2015].[1] The latter paper is particularly relevant for the present analysis since it emphasizes the importance of the choice between different mortgage products for mortgage default. Moreover, Cocco [2013] empirically analyzes the advantages and dangers of subprime mortgage contracts. The current paper contributes to this literature by analyzing how self-control affects both housing decisions and the choice between mortgages with different down payment requirements. Ghent [2015] and Kovacs [2016] also consider housing in the presence of present biased preferences. Ghent [2015] compares in a general equilibrium

[1] The current paper focuses on life-cycle aspects of the housing and mortgage choice in partial equilibrium with a realistically flexible choice set for households. Nevertheless, it is closely related to the literature on general equilibrium implications of housing decisions and mortgage underwriting standards. The most relevant papers are Corbae and Quintin [2015] and Favilukis, Ludvigson, and Van Nieuwerburgh [2017], who quantitatively analyze the aggregate effects of relaxing collateral requirements in mortgage contracts.

framework how introducing low down payment mortgages affects the welfare of people who discount the future quasi-hyperbolically (a way to model time-inconsistency suggested by Laibson [1997]). While she concludes that low down payment mortgages are welfare-improving for present biased households, the current paper obtains the opposite result. The discrepancy stems partly from the different representations of present bias in household preferences[2] and partly from how the households' choice set is modeled in both papers. The current paper allows for a very flexible choice set for households with continuous choices in both the house size and mortgage size subject to minimum down payment restrictions. This flexibility gives households more margins to adjust in reaction to a policy change, which leads to qualitatively and quantitatively different assessments of regulation policies. Kovacs [2016] estimates the average degree of self-control using a Euler equation approach. The current paper has a different goal: it allows for heterogeneity in the degree of self-control and analyzes how differences in self-control affect housing and mortgage decisions. It then emphasizes the differential welfare effect of regulation in the mortgage market on agents with different degrees of self-control problems.

The second stream of literature that this paper directly relates to is the analysis of present bias in other household decisions. Temptation, self-control, and a desire for commitment were found to play a role in various contexts, both nonfinancial[3] and financial. In the context of household finance, Meier and Sprenger [2010] show empirically that the degree of present bias is an important determinant of credit card borrowing. Laibson, Repetto, and Tobacman [2007] and Nakajima [2017] study the effects of present bias on credit card debt in a quantitative life-cycle model. Moreover, Heidhues and Koszegi [2010] show that regulation of late fees in credit contracts can improve welfare if people naïvely underestimate their time-inconsistency. Finally, Ameriks et al. [2007] find survey evidence that problems of self-control are correlated with wealth accumulation. The contribution of the current paper is to study the effects of self-control on the housing and mortgage decision—for most households, the most important financial decision that they have to make during their lifetime.

[2] The costs of self-control and desire for commitment are different for hyperbolic discounting and dynamic self-control preferences. Under hyperbolic discounting, agents have a desire to commit themselves only if they expect their future selves to give in to the temptation that they encounter. Under dynamic self-control preferences, on the other hand, agents have an incentive for commitment even if they expect to resist the temptation in the future (since exercising self-control is costly). Toussaert [2018] exploits this difference to test whether people exhibit hyperbolic discounting or dynamic self-control preferences in a lab setting and finds support for dynamic self-control preferences.

[3] Nonfinancial contexts where present bias and a desire for commitment were empirically found to be important include the choice of gym contracts (DellaVigna and Malmendier, 2006) and in the workplace (Kaur, Kremer, and Mullainathan, 2015). From a theoretical perspective, Gul and Pesendorfer [2007] show that temptation preferences can be used to model drug addiction and Krusell, Kuruscu, and Smith, Krusell, Kuruscu, and Smith [2009, 2010] introduce self-control problems in the context of a standard growth model.

1. Model of Housing and Mortgages in the Presence of Self-Control

In this section, I describe the structural model that I use to analyze the effects of self-control on the housing and mortgage choice. First, I specify how costs of self-control are modeled and show what the main driving forces are in this preference specification. Second, I describe the life-cycle model of housing and mortgages.

1.1 Preference specification

To model the costs of self-control, I assume that households have Dynamic Self-Control (DSC) preferences (Gul and Pesendorfer, 2001, 2004). These preferences capture the idea that agents are subject to temptation and suffer from the costs of self-control if they want to resist this temptation. In this paper, agents receive utility from nondurable consumption C and housing services H. The detailed functional form of the per-period utility is as follows[4]:

$$U(C_t,H_t)= u(C_t,H_t)+\lambda\cdot\Big(u(C_t,H_t)-T(B_t)\Big), \tag{1}$$

$$\text{where}\ \ T(B_t)=\max_{\{\tilde{C}_t,\tilde{H}_t\}\in B_t} u(\tilde{C}_t,\tilde{H}_t). \tag{2}$$

The per-period utility consists of two terms. The first term refers to the felicity the agent receives from consuming a consumption bundle $\{C_t,H_t\}$. The second term shows that the agent has to exercise self-control in order to implement this choice of consumption bundle. In particular, the agent always faces the temptation $T(B_t)$ to maximize his *current* period utility, that is, to choose the consumption bundle $\{\tilde{C}_t,\tilde{H}_t\}$ within his budget set B_t that would give the highest felicity in this period. However, agents do not maximize their current felicity but instead maximize their discounted *lifetime* utility. Hence, the term $(u(C_t,H_t)-T(B_t))$ is typically negative and represents the costs of exercising self-control. The parameter λ governs how severe the temptation is. This is the central parameter to this specification of DSC preferences. If λ is equal to zero, the self-control term drops out and per-period utility simplifies to standard preferences without problems of self-control. As λ increases, however, the costs of self-control become more severe.

DSC preferences are defined not only over the actually chosen consumption bundle but over the whole budget set B_t. Specifically, the most tempting option within the budget set directly enters the utility. In order to understand the behavior of DSC agents, it is therefore crucial to understand how their current actions affect their future budget set and hence their future costs of self-control. To illustrate the different driving forces of DSC preferences, it is instructive to

[4] The present formulation is a special case of the specification in Gul and Pesendorfer, Gul and Pesendorfer [2001, 2004] in the sense that commitment utility and temptation utility have the same functional form up to a constant λ.

consider a simple dynamic consumption-savings optimization problem without housing:

$$V(X_t) = \max_{C_t \in B_t} U(C_t) + \beta \cdot V(X_{t+1})$$
$$= \max_{C_t \in B_t} u(C_t) + \lambda \cdot \big(u(C_t) - T(B_t)\big) + \beta \cdot V(X_{t+1}), \tag{3}$$

where X_t is available cash-on-hand that follows a law of motion $X_{t+1} = (1+r)S_t$ and S_t is savings. The budget set B_t is defined by the constraint that $C_t + S_t \leq X_t$. Optimizing over savings leads to the following Euler Equation:

$$-(1+\lambda)\frac{\partial u(C_t)}{\partial S_t} = \beta \cdot \left[\frac{\partial u(C_{t+1})}{\partial S_t} + \lambda \cdot \left(\frac{\partial u(C_{t+1})}{\partial S_t} - \frac{\partial T(B_{t+1})}{\partial S_t}\right)\right]. \tag{4}$$

Equation (4) emphasizes that the problem of self-control has two effects: first, as can be seen on the left-hand side, the marginal utility of giving up consumption is increased, which makes the agent effectively more impatient.[5] This effect is what I refer to as the *impatience effect*. Second, on the right-hand side, the effects of current choices on future costs of self-control enter the optimality condition. The agent takes into account that his current choices change tomorrow's budget set B_{t+1} and hence tomorrow's temptation $T(B_{t+1})$. I call this second effect the *anticipation effect*.[6] Note that in this illustrative example there is only one choice variable, which is continuous. The anticipation effect will become even more important, however, when discrete choices are considered such as buying a house instead of renting or defaulting on a mortgage. The reason is that these discrete choices lead to nonconvex changes in future budget sets.

From the introduction of DSC preferences in this section, we thus make two observations. First, the preferences are defined on the whole budget set of the agent, not only on the actions actually taken. It is hence crucial to identify the most tempting option in the choice set since all possible actions are evaluated against this temptation. Second, there are two driving forces behind DSC preferences: an impatience effect and an anticipation effect. The optimal decision will trade off these two effects.

1.2 Model of housing and mortgages

The model I use to analyze the effects of self-control on the housing and mortgage choice is a partial equilibrium life-cycle model. All households are born in period $t=1$ and live for T periods. They work for the first T^R periods of their lives and are in retirement for the last $T-T^R$ periods.

[5] An equivalent way of expressing this effect would be to divide the equation by $(1+\lambda)$ so that the effective discount factor would be $\beta/(1+\lambda) \leq \beta$.

[6] This effect arises since agents are sophisticated in the sense that they fully anticipate their problem of self-control in the future.

There are three types of assets in this model: liquid savings S, houses H, and mortgages M. Liquid savings are risk-free and can be used for saving and unsecured borrowing. Households can borrow in this asset up to an endogenous borrowing limit: all households can borrow in the form of credit card debt (up to a fraction of their income). In addition, homeowners can borrow through home equity lines of credit (HELOCs) so that their borrowing limit also depends on their house value and mortgage balance.

The second type of asset, houses, serves two purposes. On the one hand, agents receive utility from consuming housing services. The felicity function has the following form:

$$u(C,H)=\frac{\left(C^{1-\theta}H^{\theta}\right)^{1-\sigma}}{1-\sigma}. \tag{5}$$

On the other hand, houses are an illiquid form of investment. The illiquidity is modeled in the sense that if agents decide to sell their house this transaction only takes place with a delay of one period. This is in contrast to liquid savings, which can be spent immediately.

The third class of assets, mortgages, can be used to finance the purchase of a house. They are fixed-rate mortgages, and the repayment schedule is explicitly modeled. As with the house size, agents have a continuous choice of mortgage size but have to satisfy two constraints: first, there is a loan-to-value constraint (LTV) such that the agent can only borrow up to a certain fraction of the house value. The second constraint is a payment-to-income constraint (PTI), which restricts the fixed mortgage payment to be smaller than a maximum multiple of the agent's income. Mortgages are defaultable, and risk-neutral lenders take this default risk into account when pricing mortgages. In equilibrium, banks therefore offer a mortgage price schedule that depends on the full portfolio of the household.

Households face uninsurable, idiosyncratic income risk as in Deaton [1991] and Carroll [1997]. During working life, the income process has the following form:

$$Y_{it}=\bar{Y}_{it}\cdot V_{it}; \tag{6}$$

$$\bar{Y}_{it}=G_t\cdot\bar{Y}_{it-1}\cdot N_{it}; \qquad t=1\ \dots\ T^R. \tag{7}$$

Income Y_{it} of household i in period t can be decomposed in a permanent income component $\bar{Y}_{it}$ and a mean of one transitory shock $V_{it}\sim\log N(-\sigma_V^2/2,\sigma_V)$. The permanent income component follows a random walk with drift, where $N_{it}\sim\log N(-\sigma_N^2/2,\sigma_N)$ is a permanent shock and G_t reflects a deterministic, hump-shaped life-cycle profile.[7] During retirement, there is no income uncertainty and

[7] Period t is equivalent to a specific age of the household since all households start their life in period $t=1$.

the agents receive a fraction ς of their permanent income in the last working life period:

$$Y_{it} = \varsigma \cdot \bar{Y}_{iT^R}; \qquad t = T^R + 1 \ldots T. \tag{8}$$

The choice set of the agents differs whether they own a house or not. In the next subsections, I describe the two optimization problems in detail. Moreover, for both renters and homeowners I discuss the most tempting option in their choice set and how this temptation is affected by their previous actions and by the market environment. Finally, I describe the optimization problem of the risk-neutral mortgage lenders and how the mortgage pricing schedule is determined.

1.2.1 Optimization problem of a renter. If the agent enters the period as a renter, he has the choice to keep renting or to buy a house. If he keeps renting, he solves the following optimization problem[8]:

$$V_t^{rent}(X_t, \bar{Y}_t) = \max_{S_t, H_t} \; (1+\lambda)\, u(C_t, H_t) - \lambda\, T_t^{noh}(X_t, \bar{Y}_t) + \beta \cdot \mathsf{E}\left[V_{t+1}^{noh}(X_{t+1}, \bar{Y}_{t+1})\right]; \tag{9}$$

$$\text{s.t.} \qquad C_t = X_t - S_t - P_t^R \cdot H_t; \tag{10}$$

$$X_{t+1} = S_t \cdot R^{noh}(S_t) + Y_{t+1}; \tag{11}$$

$$S_t \geq -\phi_{CC} \bar{Y}_t. \tag{12}$$

Given the state variables cash-on-hand X_t and permanent income $\bar{Y}_t$, he has two continuous choice variables: savings S_t and house size to be rented H_t. $T_t^{noh}(X_t, \bar{Y}_t)$ is the temptation that an agent faces who enters the period without a house. Equation (10) determines the implied nondurable consumption C_t where P_t^R is the rental price of one unit of housing services. The next period, the agent will enter the period still without a house and with cash-on-hand X_{t+1} which is determined according to the law of motion in Equation (11), where $R^{noh}(S_t)$ is the interest rate on liquid assets. It depends on whether the household saves or borrows:

$$R^{noh}(S_t) = \begin{cases} 1 + r_S & \text{if} \quad S_t \geq 0 \\ 1 + r_B & \text{if} \quad S_t < 0 \end{cases}. \tag{13}$$

Equation (12) shows that households are allowed to borrow up to a fraction ϕ_{CC} of their permanent income. This specification hence allows households to have unsecured borrowing in the form of credit card debt.

If the agent chooses to buy a house, his optimization problem is the following:

$$V_t^{buy}(X_t, \bar{Y}_t) = \max_{S_t, \bar{H}, M_t} \; (1+\lambda)\, u(C_t, \bar{H}) - \lambda\, T_t^{noh}(X_t, \bar{Y}_t)$$
$$+ \beta \cdot \mathsf{E}\left[V_{t+1}^{house}(X_{t+1}, \bar{H}, M_{t+1}, 1, \bar{Y}_{t+1})\right]; \tag{14}$$

[8] To simplify notation, I drop the subscript i for all subsequent optimization problems.

$$\text{s.t.} \qquad C_t = X_t - (1+\delta_B)\cdot P_t^H \bar{H} + q_t^M(S_t,\bar{H},M_t,1,\bar{Y}_t)M_t - \delta_M M_t - S_t; \tag{15}$$

$$M_t \leq \phi_v \cdot P_t^H \bar{H}; \tag{16}$$

$$Q(M_t,1,t) \leq \phi_y \cdot \bar{Y}_t; \tag{17}$$

$$X_{t+1} = S_t \cdot R^{house}(S_t,\bar{H},M_t,1,t) + Y_{t+1}; \tag{18}$$

$$M_{t+1} = M_t(1+r_M); \tag{19}$$

$$S_t \geq -(\phi_{CC}\bar{Y}_t + S_{HELOC}^{max}(\bar{H},M_t,1,t,\bar{Y}_t)). \tag{20}$$

There are now three continuous choice variables: liquid savings S_t, the size of the house to buy $\bar{H}$, and the size of the mortgage M_t. To buy a house, the agent has to pay transaction costs on the house (δ_B) and on the mortgage (δ_M). Moreover, mortgages are defaultable and the banks will price in this default risk, so that the household faces an equilibrium mortgage price schedule q_t^M that depends on the household's full asset position. Equations (16) and (17) represent the restrictions on the mortgage size: the ratio of mortgage-to-house value cannot exceed the fraction ϕ_v, which is the maximum loan-to-value ratio. Moreover, the payment-to-income restriction implies that the mortgage payment Q must not exceed a multiple ϕ_y of the agent's permanent income. Since mortgages are fixed-term mortgages and both the term of the mortgage and the mortgage rate (r_M) are fixed, the mortgage payment is determined by the outstanding mortgage and the age of the mortgage according to the following formula:

$$Q(M,a,t) = \frac{M}{1+r_M}\cdot\kappa_a; \qquad a \geq 1 \tag{21}$$

$$\text{where} \qquad \kappa_1 = \frac{r_M}{1-(1+r_M)^{-\tau}}; \tag{22}$$

$$\kappa_a = \begin{cases} \frac{\kappa_{a-1}}{1+r_M-\kappa_{a-1}} & a=2,\ldots\tau \\ 0 & a>\tau \end{cases}; \tag{23}$$

$$\tau = \min\left[\tau^s, T-t-a\right], \tag{24}$$

where the fixed term of the mortgage τ is either equal to the standard term τ^s or the remaining lifetime at origination in case that is shorter.

Equations (18) and (19) give the laws of motion for cash-on-hand and the mortgage balance, respectively. Note that in the period in which the mortgage is taken out the agent does not make a mortgage payment, such that next period's mortgage balance is equal to the current balance subject to the mortgage rate r_M. If households buy a house, they also have the possibility to borrow in the form of home equity lines of credit (HELOCs). These are reflected in a loser borrowing limit on liquid assets as seen in Equations (20) and (25). The maximum amount that can be borrowed in the form of HELOCs is the amount that makes either the combined LTV or combined PTI restriction binding, where "combined" refers to the combined amount of borrowing through mortgages and HELOCs:

$$S^{max}_{HELOC}(\bar{H},M_t,a,t,\bar{Y}_t)=\min(\phi_v\cdot P^H_t\bar{H}-M_t,\phi_y\cdot\bar{Y}_t-Q(M_t,a,t)). \tag{25}$$

The interest rate on liquid assets for a homeowner (including those households that buy a house in the current period) is determined by the full portfolio choice of the household:

$$R^{house}(S_t,\bar{H},M_t,a,t)=\begin{cases} r_S & \text{if } S_t\geq 0\\ r_M & \text{if } -S^{max}_{HELOC}(\bar{H},M_t,a,t,\bar{Y}_t)\leq S_t<0\\ (1+r_B)+(r_B-r_M)\cdot & \text{if } S_t<-S^{max}_{HELOC}(\bar{H},M_t,a,t,\bar{Y}_t)\\ \frac{S^{max}_{HELOC}(\bar{H},M_t,a,t,\bar{Y}_t)}{S_t} & \end{cases}. \tag{26}$$

It not only depends on the amount of liquid assets but also on the house and mortgage size since those determine the maximum amount that can be borrowed through HELOC. This specification of the interest rates assumes that households will always first exhaust borrowing through HELOC before borrowing through credit card debt. This is also the optimal behavior as HELOC borrowing is cheaper than borrowing through credit cards ($r_M<r_B$).

Finally, the decision to buy a house or to keep renting is determined by which behavior yields the higher value. The value of entering the period without a house can hence be summarized as follows:

$$V^{noh}_t(X_t,\bar{Y}_t)=\max\left\{V^{rent}_t(X_t,\bar{Y}_t),V^{buy}_t(X_t,\bar{Y}_t)\right\}. \tag{27}$$

1.2.2 Temptation of a renter. To understand the behavior of agents with costs of self-control, it is important to understand what the most tempting option is in their choice set, that is, the temptation $T^{noh}_t(X_t,\bar{Y}_t)$ they evaluate their actual choice against. For a renter, this could be one of two possibilities. First, it could be most tempting to keep renting and to spend all available cash-on-hand as well as the maximum amount of credit card debt possible on current consumption and on renting a house:

$$T^{rent}_t(X_t,\bar{Y}_t)=\max_{\tilde{H}_t}\ u(X_t+\phi_{CC}\bar{Y}_t-P^R\cdot\tilde{H}_t,\tilde{H}_t). \tag{28}$$

Second, the temptation could be to buy a house and to choose the house size, mortgage size, and amount of borrowing in liquid assets to maximize current period utility:

$$T_t^{buy}(X_t, \bar{Y}_t) = \max_{\tilde{H}, \tilde{M}_t, \tilde{S}_t} \; u(\tilde{C}_t, \mu \tilde{H}); \tag{29}$$

$$\text{s.t.} \qquad \tilde{C}_t = X_t - (1+\delta_B) \cdot P_t^H \tilde{H} + q_t^M(\tilde{S}_t, \tilde{H}, \tilde{M}_t, 1, \bar{Y}_t)\tilde{M}_t - \delta_M \tilde{M}_t - \tilde{S}_t; \tag{30}$$

$$\tilde{M}_t \le \phi_v \cdot P_t^H \tilde{H}; \tag{31}$$

$$Q(\tilde{M}_t, 1, t) \le \phi_y \cdot \bar{Y}_t; \tag{32}$$

$$\tilde{S}_t \ge -(\phi_{CC} \bar{Y}_t + S_{HELOC}^{max}(\tilde{H}, \tilde{M}_t, 1, t, \bar{Y}_t)). \tag{33}$$

Note that in this second case it is not clear whether the household is tempted to exhaust all possible borrowing since the household faces an equilibrium mortgage price schedule, which might imply an interior level of borrowing that maximizes available resources and hence current period utility.

The overall temptation that the agent faces is the maximum of the two options:

$$T_t^{noh}(X_t, \bar{Y}_t) = \max\left\{ T_t^{rent}(X_t, \bar{Y}_t), T_t^{buy}(X_t, \bar{Y}_t) \right\}. \tag{34}$$

Which of these options is more tempting depends crucially on the minimum down payment requirement (the LTV constraint). If the required down payment is low, the agent can buy a very large house while hardly paying anything at the time of purchase. This gives high instantaneous utility and is hence very tempting. If, on the other hand, the down payment requirement is high, either the agent can only buy a much smaller house for the same down payment or he has to cut down consumption. Either way, the instantaneous utility and hence the temptation is lower.

1.2.3 Optimization problem of a homeowner. An agent who enters the period as a homeowner has four possibilities: he can keep the house and keep repaying his mortgage; he can refinance his mortgage, decide to sell the house, or default on his mortgage. If he decides to keep his house and keep repaying his mortgage, he has to solve the following optimization problem:

$$\begin{aligned} V_t^{repay}(X_t, \bar{H}, M_t, a, \bar{Y}_t) = \max_{S_t} \; & (1+\lambda)\, u(C_t, \bar{H}) - \lambda\, T_t^{house}(X_t, \bar{H}, M_t, a, \bar{Y}_t) \\ & + \beta \cdot \mathsf{E}\left[V_{t+1}^{house}(X_{t+1}, \bar{H}, M_{t+1}, a+1, \bar{Y}_{t+1}) \right]; \end{aligned} \tag{35}$$

$$\text{s.t.} \qquad C_t = X_t - Q(M_t, a, t) - \psi_M P_t^H \bar{H} - S_t; \tag{36}$$

$$X_{t+1} = S_t \cdot R^{house}(S_t, \bar{H}, M_t, a, t) + Y_{t+1}; \tag{37}$$

$$M_{t+1} = (M_t - Q(M_t, a, t))(1+r_M); \tag{38}$$

$$S_t \ge -(\phi_{CC} \bar{Y}_t + S_{HELOC}^{max}(\bar{H}, M_t, a, t, \bar{Y}_t)). \tag{39}$$

He enters the period with five state variables: cash-on-hand X_t, the size of his house $\bar{H}$, the balance of his outstanding mortgage M_t, the time since origination of his mortgage a, and his permanent income $\bar{Y}_t$. The agent makes the mortgage payment Q, which is required to repay the mortgage on schedule. Equation (36) states that consumption is equal to remaining cash-on-hand after mortgage payment Q, maintenance costs ψ_M, and liquid savings S_t. The only choice variable in this situation is hence the amount of liquid savings S_t, which has to satisfy the borrowing constraint coming from credit card borrowing and HELOCs. The next period, the agent will enter with the same house but a lower mortgage (Equation (38)), which is one period older.

If the agent decides to refinance his mortgage, he faces the following problem:

$$V_t^{ref}(X_t,\bar{H},\bar{M},\bar{Y}_t)=\max_{S_t,M_t}\ (1+\lambda)\ u(C_t,\bar{H})-\lambda\ T_t^{house}(X_t,\bar{H},\bar{M},a,\bar{Y}_t) + \beta\cdot\mathsf{E}\left[V_{t+1}^{house}(X_{t+1},\bar{H},M_{t+1},1,\bar{Y}_{t+1})\right]; \tag{40}$$

$$\text{s.t.} \qquad C_t=X_t-\psi_M P_t^H\bar{H}-\bar{M}+q_t^M(S_t,\bar{H},M_t,1,\bar{Y}_t)M_t-\delta_M M_t-S_t; \tag{41}$$

$$M_t\le\phi_v\cdot P_t^H\bar{H}; \tag{42}$$

$$Q(M_t,1,t)\le\phi_y\cdot\bar{Y}_t; \tag{43}$$

$$X_{t+1}=S_t\cdot R^{house}(S_t,\bar{H},M_t,1,t)+Y_{t+1}; \tag{44}$$

$$M_{t+1}=M_t(1+r_M); \tag{45}$$

$$S_t\ge-(\phi_{CC}\bar{Y}_t+S_{HELOC}^{max}(\bar{H},M_t,1,t,\bar{Y}_t)). \tag{46}$$

He has to choose the optimal balance of a new mortgage and liquid savings based on his state variables cash-on-hand X_t, the house size he owns $\bar{H}$, the old mortgage balance outstanding $\bar{M}$, and his permanent income $\bar{Y}_t$. He repays his existing mortgage and takes out a new one subject to transaction costs (Equation (41)). As in the case when he buys a house, the new mortgage balance has to satisfy both LTV and LTI constraints (Equations (42) and (43)). The next period, he will enter with the same house but a new mortgage, which will be one period old. Note that the agent does not have to take out a new mortgage if he decides to refinance. Instead, he can choose to repay his mortgage and not take out a new one.[9]

The third possibility of a homeowner is to sell his house. Houses are illiquid assets that cannot be sold immediately. Instead, the agent has to decide to sell the house in the current period, but the transaction only takes place during the transition from the current period to the next. This implies that in the current

[9] This is equivalent to taking out a new mortgage with zero balance.

period, the agent still has to pay maintenance costs and to make the mortgage payment required to repay the mortgage on schedule. The next period, the household will enter without a house but with his cash-on-hand increased by the proceeds from selling the house. He will be able to buy another house immediately. In particular, if he wants to upsize or downsize, he can do that by deciding to sell now and by buying the desired house size next period. In detail, the problem of an agent who sells his house is the following:

$$V_t^{sell}(X_t,\bar{H},M_t,a,\bar{Y}_t)=\max_{S_t}\ (1+\lambda)\,u(C_t,\bar{H})-\lambda\ T_t^{house}(X_t,\bar{H},M_t,a,\bar{Y}_t)$$

$$+\beta\cdot\mathsf{E}\left[V_{t+1}^{noh}(X_{t+1},\bar{Y}_{t+1})\right]; \tag{47}$$

$$\text{s.t.}\qquad C_t=X_t-\psi_M P_t^H\bar{H}-Q(M_t,a,t)-S_t; \tag{48}$$

$$X_{t+1}=\ S_t R^{house}(S_t,\bar{H},M_t,a,t)+Y_{t+1}$$

$$+(1-\delta_S)P_{t+1}^H\bar{H}-(M_t-Q(M_t,a,t))(1+r_M); \tag{49}$$

$$S_t\geq-(\phi_{CC}\bar{Y}_t+S_{HELOC}^{max}(\bar{H},M_t,a,t,\bar{Y}_t)). \tag{50}$$

The choice to introduce the delay in selling but not in buying is deliberate. It implies that buying a house is associated with the potential temptation to buy a house that is too expensive while home equity is illiquid and cannot be spent immediately. In reality, the purchase of a house is not instantaneous. However, people start planning and dreaming about how to alter or decorate the house the moment they come to the viewing. Their utility is thus affected early on in the purchasing process. In contrast, sellers only receive the proceeds from the sale at the end of this process. There is hence a significant amount of time between the decision to sell and being able to actually spend the money you obtain by selling. This is captured by the delay in the optimization problem of a seller.

The last option of a homeowner is to default on his mortgage. In this case, there are four consequences. First, he immediately loses his house and hence has to rent in this period. Second, his mortgage balance is immediately set to zero. Third, he will be excluded from the housing market for a random number of periods.[10] Lastly, if he had positive home equity in the house prior to default, he will receive the proceeds from the house sale in the next period if there is anything left after the mortgage has been repaid. However, since the sales price of a foreclosed home is typically lower than for a normal sale, the transaction costs will be higher in case of default than in case of selling ($\delta_D>\delta_S$).

[10] In reality, a foreclosure event is removed from the credit report of the borrower after a fixed number of years. However, as is often done in the literature of default (see, e.g., Chatterjee et al. [2007] and Mitman [2016]), I choose to model the time in the exclusion state as stochastic to facilitate computation. When calibrating the model, the probability of reentering will be chosen so that the average number of years with a bankruptcy flag corresponds to U.S. regulations.

The optimization problem of a defaulting household looks as follows:

$$V_t^{def}(X_t,\bar{H},M_t,\bar{Y}_t)=\max_{S_t,H_t}(1+\lambda)\,u\big(C_t,H_t\big)-\lambda\,T_t^{house}(X_t,\bar{H},M_t,a,\bar{Y}_t)$$
$$+\beta\big((1-\omega)\mathsf{E}\big[V_{t+1}^{ex}(X_{t+1},\bar{Y}_{t+1})\big]+\omega\mathsf{E}\big[V_{t+1}^{noh}(X_{t+1},\bar{Y}_{t+1})\big]\big); \tag{51}$$

$$\text{s.t.}\qquad C_t=X_t-P_t^R\cdot H_t-S_t; \tag{52}$$

$$X_{t+1}=S_tR^{noh}(S_t)+Y_{t+1}+\max\big[0,(1-\delta_D)P_{t+1}^H\bar{H}-M_t(1+r_M)\big]; \tag{53}$$

$$S_t\geq-\phi_{CC}\bar{Y}_t. \tag{54}$$

Equation (51) states that the agent will reenter the housing market only with probability ω. With probability $(1-\omega)$, the agent will be excluded and hence does not have the option to buy a house:

$$V_t^{ex}(X_t,\bar{Y}_t)=\max_{S_t,H_t}(1+\lambda)\,u(C_t,H_t)-\lambda\,T_t^{ex}(X_t,\bar{Y}_t)$$
$$+\beta\big((1-\omega)\mathsf{E}\big[V_{t+1}^{ex}(X_{t+1},\bar{Y}_{t+1})\big]+\omega\mathsf{E}\big[V_{t+1}^{noh}(X_{t+1},\bar{Y}_{t+1})\big]\big); \tag{55}$$

$$\text{s.t.}\qquad C_t=X_t-P_t^R\cdot H_t-S_t; \tag{56}$$

$$X_{t+1}=S_tR^{noh}(S_t)+Y_{t+1}; \tag{57}$$

$$S_t\geq-\phi_{CC}\bar{Y}_t; \tag{58}$$

$$T_t^{ex}(X_t,\bar{Y}_t)=\max_{\tilde{H}_t}\;u(X_t+\phi_{CC}\bar{Y}_t-P^R\cdot\tilde{H}_t,\tilde{H}_t). \tag{59}$$

Overall, a homeowner will choose the option that leads to the highest value:

$$V_t^{house}(X_t,\bar{H},M_t,a,\bar{Y}_t)=\max\Big[V_t^{repay}(X_t,\bar{H},M_t,a,\bar{Y}_t),\;V_t^{ref}(X_t,\bar{H},M_t,\bar{Y}_t),$$
$$V_t^{sell}(X_t,\bar{H},M_t,a,\bar{Y}_t),\;V_t^{def}(X_t,\bar{H},M_t,\bar{Y}_t)\Big]. \tag{60}$$

1.2.4 Temptation of a homeowner. As in the case of a renter, it is important to identify the most tempting option $T_t^{house}(X_t,\bar{H},M_t,a,\bar{Y}_t)$ in the choice set of a homeowner. There are three candidates for the most tempting option. First, it could be most tempting to default on the mortgage. In this case, the homeowner immediately loses his house but can use all cash-on-hand and available credit card borrowing for consumption and renting a house:

$$T_t^{def}(X_t,\bar{Y}_t)=\max_{\tilde{H}_t}\;u\Big(X_t+\phi_{CC}\bar{Y}_t-P^R\cdot\tilde{H}_t\;\tilde{H}_t\Big). \tag{61}$$

Second, it could be most tempting to keep the house, make the mortgage payment and pay maintenance costs, and spend all remaining cash-on-hand on current consumption[11]:

$$T_t^{repay}(X_t, \bar{H}, M_t, a, \bar{Y}_t) = u\Big(X_t + \phi_{CC}\bar{Y}_t + S_{HELOC}^{max}(\bar{H}, M_t, a, t, \bar{Y}_t) - \psi_M P_t^H \bar{H} - Q(M_t, a, t),\ \bar{H}\Big). \tag{62}$$

How tempting this second option is relative to the first is strongly affected by the size of the required mortgage payment relative to the size of the house. Default will be tempting if the mortgage payment is too large relative to the instantaneous utility the agent receives from his house. If the agent wants to use the house and mortgage as a commitment device, he needs to ensure that default is not tempting. This effectively leads to an upper bound for the size of the mortgage relative to the house size, that is, for the LTV ratio.

However, there is a third candidate for the most tempting option: it can be most tempting to keep the house and extract the maximum amount of home equity through refinancing and liquid borrowing:

$$T_t^{ref}(X_t, \bar{H}, \bar{M}, \bar{Y}_t) = \max_{\tilde{S}_t, \tilde{M}_t} \ u(\tilde{C}_t, \mu\bar{H}); \tag{63}$$

$$\text{s.t.} \qquad \tilde{C}_t = X_t - \psi_M P_t^H \bar{H} - \bar{M} + q_t^M(S_t, \bar{H}, \tilde{M}_t, 1, \bar{Y}_t)\tilde{M}_t - \delta_M \tilde{M}_t - \tilde{S}_t; \tag{64}$$

$$\tilde{M}_t \leq \phi_v \cdot P_t^H \bar{H}; \tag{65}$$

$$Q(\tilde{M}_t, 1, t) \leq \phi_y \cdot \bar{Y}_t; \tag{66}$$

$$\tilde{S}_t \geq -(\phi_{CC}\bar{Y}_t + S_{HELOC}^{max}(\bar{H}, \tilde{M}_t, 1, t, \bar{Y}_t)). \tag{67}$$

This option is more tempting the more home equity there is to extract, which reduces the commitment effect of houses and mortgages. The overall temptation that a homeowner faces is given by the maximum of the three options:

$$T_t^{house}(X_t, \bar{H}, M_t, a, \bar{Y}_t) = \max\Big[\ T_t^{def}(X_t, \bar{Y}_t),\ T_t^{repay}(X_t, \bar{H}, M_t, a, \bar{Y}_t),\ T_t^{ref}(X_t, \bar{H}, M_t, \bar{Y}_t)\Big]. \tag{68}$$

1.2.5 Optimization problem of the mortgage lenders. Mortgage lenders operate in a competitive market and are risk neutral. They face exogenous financing costs of r_S and have to pay monitoring costs γ for every dollar of mortgage outstanding. Moreover, since mortgages are defaultable, lenders need to take the default risk into account when pricing the mortgage. While all

[11] Note that in case of selling the highest possible current utility is the same as in case of repaying since the agent still owns the house in the current period.

mortgages charge the same interest rate r_M, the default risk is captured through the price of the mortgage, that is, how much of the face value of the mortgage is paid out to the household when the mortgage is issued. Mortgage lenders set this price such that they ensure that they make zero profits in expectation.

One complication is that the self-control type of a household is private knowledge and not observable. Mortgage lenders only know the share of each type in the population, $\pi(\lambda)$, but cannot directly condition their price on the self-control type. The mortgage price schedule is therefore pooled over all self-control types. It satisfies the following condition:

$$
\begin{aligned}
q_t^M(S_t,\bar{H},M_t,a,\bar{Y}_t)M_t = &\frac{1}{(1+r_S+\gamma)}\cdot\sum_{\lambda\in\Lambda}\pi(\lambda)\mathsf{E}\Bigg\{ \\
&\mathbb{1}_{Def^{\lambda}_{t+1}}\cdot\min\Big[M_{t+1},(1-\delta_D)P^H_{t+1}\bar{H}\Big] \\
&+\mathbb{1}_{Rep^{\lambda}_{t+1}}\cdot\Big[Q_{t+1}(M_{t+1},a+1,t+1) \\
&\quad +q^M_{t+1}(S^{repay,\lambda}_{t+1},\bar{H},M_{t+1}-Q(M_{t+1},a+1,t+1),a+1,\bar{Y}_{t+1}) \\
&\quad \cdot(M_{t+1}-Q_{t+1}(M_{t+1},a+1,t+1))\Big] \\
&+\mathbb{1}_{Sell^{\lambda}_{t+1}}\cdot\Big[Q_{t+1}(M_{t+1},a+1,t+1) \\
&\quad +\frac{1}{(1+r_S+\gamma)}\cdot(M_{t+1}-Q_{t+1}(M_{t+1},a+1,t+1))\cdot(1+r_M)\Big] \\
&+\mathbb{1}_{Ref^{\lambda}_{t+1}}\cdot M_{t+1}\Bigg\},
\end{aligned}
\tag{69}
$$

where $\mathbb{1}_{Def^{\lambda}_{t+1}}$ represents an indicator function that is equal to one if households of self-control type λ choose to default in period $t+1$ (and similarly for repaying, selling, and refinancing).[12] Equation (69) shows that today's value of the mortgage is equal to the discounted expected value tomorrow. The first case refers to the situation where the household defaults on the mortgage: the bank receives the proceeds from selling the house (subject to the increased discount of selling a foreclosed home) unless that value exceeds the outstanding mortgage balance. The second case captures the situation where the household keeps repaying the mortgage on schedule: the lender receives the mortgage payment and still holds the remaining mortgage, which is priced at tomorrows mortgage price for the particular household portfolio. $S^{repay,\lambda}_{t+1}$ is the amount of liquid assets a household of type λ optimally chooses in $t+1$ if he has state variables $(X_{t+1},\bar{H},M_{t+1},a+1,\bar{Y}_{t+1})$. The third case is that the household will decide to

[12] For readability, the state variables $(X_{t+1},\bar{H},M_{t+1},a+1,\bar{Y}_{t+1})$ have been suppressed. They are identical for all indicator functions.

Table 1
Parameter values in benchmark model

Parameter		Value	Source
Preferences			
Risk aversion	σ	2	Calibrated
Discount rate	ρ	0.06	Calibrated
Weight of housing services	θ	0.20	Piazzesi, Schneider, and Tuzel [2007]
Degrees of self-control	λ	$\{0, 0.04, 0.08, 0.12\}$	Calibrated
Shares of self-control types		$\{0.25, 0.5, 0.2, 0.05\}$	HRS 2010
Market environment			
Risk-free rate	r_S	0.018	1-year Treasury Constant Maturity
Mortgage rate	r_m	0.033	30-year Convent. Mortgage rate
Monitoring costs of lenders	γ	0.015	Own calculations
Interest rate credit cards	r_B	0.1116	Comm. Bank Int. Rate on Credit Card Plans
Credit card limit	ϕ_{CC}	0.14	Survey of Consumer Finance
House price growth rate	r_H	0.016	All trans. house price index (FHFA)
Rental price-to-house price ratio	$\frac{P_t^R}{P_t^H}$	0.0475	Davis, Lehnert, and Martin [2008]
Maintenance cost of housing	ψ_M	0.021	Kaplan and Violante [2014]
Transaction costs when buying	δ_B	0	Hsieh and Moretti [2003]
Transaction costs when selling	δ_S	0.06	Hsieh and Moretti [2003]
Transaction costs for mortgage	δ_M	0.03	Berndt, Hollifield, and Sandas [2012]
Transaction costs when defaulting	δ_D	0.27	Campbell, Giglio, and Pathak [2011]
Expected years of exclusion		7	Fair Credit Reporting Act
Income process			Cocco, Gomes, and Maenhout [2005]
Maximum LTV	ϕ_v	0.965	FHA requirement
Maximum PTI	ϕ_y	0.43	FHA requirement

sell the house in the next period: the lender receives the mortgage payment, and the remaining mortgage balance is repaid in the following period. Finally, the household can decide to refinance the mortgage, in which case the lender receives the outstanding mortgage in full in the next period.

2. Self-Control and Housing and Mortgage Choice

In this section, I describe the effects of temptation and self-control on the housing and mortgage choice. First, I describe the parameterization of the model. Second, I show that in the calibrated model self-control has economically sizable effects on the housing and mortgage choice and that these effects are in line with empirical correlations. Third, I analyze how an increase in the minimum down payment requirement or the restriction of refinancing affects the behavior and welfare of agents with different degrees of self-control.

Table 1 contains all parameter values used in the benchmark model. They are annual values that correspond to the model period of one year. The analysis starts at age 20 for agents without a college degree and at age 23 for agents with a college degree. All agents retire at age 65 and live until age 80.

2.1 Parameterization

The risk-free rate is set equal to the average one-year Treasury Constant Maturity rate over the period 1972–2006, adjusted for inflation using the

Consumer Price Index (CPI). I model 30-year fixed-rate mortgages ($\tau^s = 30$) and set the mortgage rate equal to the average real rate on 30-year conventional fixed-rate mortgages in the same time period. The monitoring costs for lenders are set such that this empirically observed average mortgage rate is optimal for lenders in equilibrium. The interest rate on credit card debt is set to the average rate from Commercial Bank Interest Rate on Credit Card Plans, available since 1994, adjusted for inflation. The credit card limit is computed from the Survey of Consumer Finances and reflects the average credit card limit (as a fraction of annual income) for households in the period 1992–2010. For the house price growth, I compute the mean growth rate in the All Transactions House Price Index for the United States in the same time period as the mortgage rate, adjusted for inflation. Davis, Lehnert, and Martin [2008] find that the average rent-price-ratio is between 0.04 and 0.05, with a tendency towards the higher end in more recent times, using data from the Decennial Census of Housing. I therefore set P^R equal to 0.0475.

For the transaction costs when buying or selling a house, I refer to Hsieh and Moretti [2003], who find that the commission charged by real estate agents is 6% of the sales price. I assume that these costs are fully paid by the seller and set $\delta_B = 0$ and $\delta_S = 0.06$. Campbell, Giglio, and Pathak [2011] study the discount that applies when a house is sold after foreclosure and find that the sales price is 27% lower on average than the price for a normal sale. I hence set $\delta_D = 0.27$. Moreover, if a house is foreclosed by law, this event will remain on the credit report of the homeowner for seven years.[13] I therefore set the probability of leaving the exclusion state such that on average the agent is excluded for seven years. For the transaction costs of taking out a mortgage, I turn to two studies: Berndt, Hollifield, and Sandas [2012] report the mean fee paid to the mortgage broker to be 3.1% of the principal amount for subprime mortgages during the period 1997–2006. Woodward and Hall [2012] find a similar number in their sample of FHA-insured mortgages in 2001. I therefore set $\delta_M = 0.03$.

The LTV and PTI restrictions are crucial for the mortgage choices in the model. To set their benchmark values, I turn to official regulations in the United States. For home buyers to be eligible for FHA insurance, they have to at least invest 3.5% of their own funds into the purchase (US Department of Housing and Urban Development, 2011). I use this value as the minimum down payment requirement, that is, I set the maximum LTV ratio to $\phi_v = 0.965$. Furthermore, for home buyers to qualify for FHA insurance, the FHA requires a mortgage payment-to-income ratio of at most 31% and the ratio of total obligations-to-income not to be higher than 43%. Since the PTI constraint applies to the sum of mortgage payments and borrowing through HELOC, I choose to set the maximum PTI constraint in accordance with the latter number.

[13] See "Fair Credit Reporting Act" by the Federal Trade Commission.

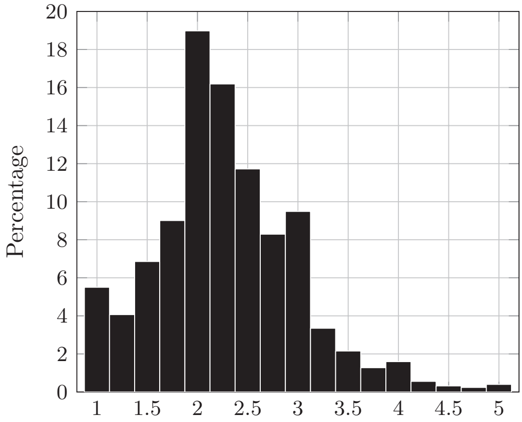

Figure 1
Measure of self-control in HRS
Higher values of the measure indicate a stronger self-reported problem of self-control. *Source:* Health and Retirement Study (HRS), wave 2010, module 5 "Personality," and own calculations.

The only preference parameter that can be set exogenously is the weight of housing services in the utility function (θ). Due to the functional form of the felicity function, I know that for a standard agent, the weight will be equal to the optimal expenditure share on housing. Piazzesi, Schneider, and Tuzel [2007] estimate this expenditure share on data from the Consumer Expenditure Survey. I therefore set θ equal to their estimate of 0.2.

Heterogeneity in self-control is at the core of the present paper. To calibrate the model I therefore have to determine both the population shares of self-control types and the levels of λ for each type. To determine appropriate group sizes, I turn to data from the Health and Retirement Study (HRS), which asked interviewees in its 2010 wave to assess their own problem of self-control.[14] Figure 1 shows the distribution of self-control in the sample, where 1 indicates "no problem of self-control" and 5 indicates a "strong problem of self-control." While the measure in the HRS cannot speak to the level of λ, I use the distribution to construct population shares. Approximately 25% of individuals answer the questions in a way that suggests no problem of self-control at all (<2), around 50% of people answer in a way that indicates a small problem (≥ 2 and <3), around 20% of individuals fall in the range ≥ 3 to <4 which I allocate to a medium-sized problem and the last 5% of people have measures ≥ 4 which I attribute to a large problem. Assuming that the first group does not have any problem of self-control at all ($\lambda = 0$), this leaves the levels of the remaining three types to be determined in the calibration.

[14] See Appendix A for the exact survey questions and construction of the measure of self-control.

To the best of my knowledge, there is no established way of choosing the self-control parameter λ or a consensus about plausible values. The values obtained in the present calibration are $\lambda = 0.04, 0.08, 0.12$. These values are in the range of the average degree of self-control of $\lambda = 0.05$ that Bucciol [2012] estimates in a structural model of liquid vs illiquid investments.[15] Moreover, to get a sense for the plausibility of the values, I follow Krusell, Kuruscu, and Smith [2009], who determine the consequences of temptation and self-control by two hypothetical welfare considerations. For each value of λ, I compute how much better off the agent would be if (1) he was relieved of his costs of self-control but could not alter his choices and (2) he was relieved of his costs of self-control and could alter his choices. I express both hypothetical welfare increases in terms of consumption equivalent, that is, the percentage increase in consumption and housing services in each period that would make a self-control agent as well off as if he was in situation (1) or (2). I report both consumption equivalents in the results of the model to get a sense for the magnitude of the problem. This ensures that the chosen values are not too extreme to be of empirical relevance.

The remaining preference parameters are also determined through calibration: the risk aversion parameter (σ) and the discount rate (ρ). The parameter values are calibrated so that the simulated median house value and median loan-to-value ratio for three different age groups (age < 35, $35 \leq$ age < 50, $50 \leq$ age < 65), as well as the ownership rate, are as close to their empirical counterparts as possible. The parameters obtained for risk aversion and for the discount rate are $\sigma = 2$ and $\rho = 0.06$, respectively. Both values are within the range commonly used in and estimated for life-cycle models (see, e.g., Gourinchas and Parker [2002]).

Table 2 shows how the benchmark model fits the targeted data moments.[16] The model matches the median profiles of house values and LTV well. In addition to the targeted moments, Figure 2 also compares the interquartile ranges between the model simulation and the data. Even though it was not targeted, the interquartile range in house values, particularly for the oldest age

[15] Readers familiar with hyperbolic discounting preferences (see, e.g., Laibson [1997]) might find these values low at first glance. However, while hyperbolic discounting (HD) and dynamic self-control (DSC) preferences have a lot in common, there is one main difference: HD agents have a desire to commit themselves only if they expect their future selves to give in to the temptation that they encounter. DSC agents, on the other hand, have an incentive for commitment even if they expect to resist the temptation in the future (since exercising self-control is costly). Toussaert [2018] exploits this difference to test whether people exhibit HD or DSC preferences in a lab setting and finds support for DSC preferences. The degree of self-control parameter λ affects the behavior of DSC agents and their desire for commitment in more situations than a comparably sized HD parameter ($\frac{1}{1+\lambda}$). Note, however, that this comparison is not exact since there is no direct mapping from the parameter λ in the current specification of DSC preferences to the parameter of present bias in HD preferences.

[16] The data moments were computed from the Survey of Consumer Finances (SCF), waves 1989–2010. The weights in the SCF are designed to correct for nonresponse, while in the Panel Study of Income Dynamics (PSID), on which the estimates of the income process are based, there is no such correction. Since nonresponse is more common for wealthier households, wealthy households are typically underrepresented in the PSID. In order to reconcile the income process from the PSID with wealth data from the SCF, I hence follow Heathcote, Perri, and Violante [2010] and adjust the SCF sample to match the wealth distribution in the PSID by dropping the wealthiest 1.47% of weighted observations (17.6% of unweighted observations) in each wave. See Appendix B for details about the model solution and simulation.

Table 2
Fit of the model

	Median house value (owners)			Median LTV (owners)			Ownership
	<35	35–50	50–65	<35	35–50	50–65	rate
Data	90	106	104	0.76	0.56	0.24	0.66
Model	89	105	115	0.70	0.57	0.22	0.74

The table compares the targeted data moments and their model equivalents. Data moments have been constructed using data from the Survey of Consumer Finances (SCF), waves 1989–2010.

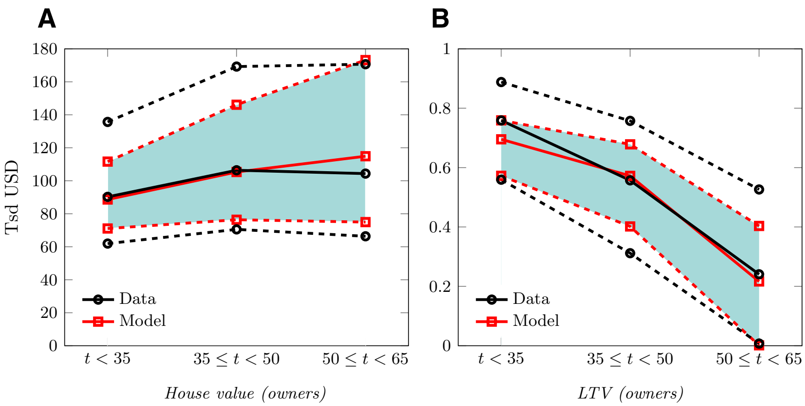

Figure 2
Model fit
The figure plots the model distribution of (panel A) house value and (panel B) loan-to-value ratio against the data distribution: solid lines refer to the median (targeted), and dashed lines depict the interquartile range (not targeted). The model-implied interquartile range is additionally shaded in gray.

group, turns out to be well approximated. This is particularly striking since the model does not exogenously impose any size restriction on the choice of house size in the households' optimization problem. The figure further shows the fit of the interquartile range in LTV over the life cycle.

Lastly, it is important to mention that there are no defaults in equilibrium.[17] This is because there is no house price risk so that people are never underwater with their mortgage. They can thus always sell their house before they would be forced to default. The only other occasion where defaults theoretically could occur is in the period immediately after mortgage origination before the household has started repayment, provided that the mortgage balance is sufficiently high. However, due to equilibrium mortgage pricing, lenders take this risk into account and charge a very high price for such a mortgage (see Appendix C for details about the equilibrium pricing schedule). This implies

[17] Note that the simulated default rate is not literally zero but for all intents and purposes is numerically zero (across all self-control types and policy scenarios at most 3e-5).

that households never choose to borrow so much that they would be in a position to default in the following period.

Nevertheless, it is important to allow for the possibility to default in the presence of self-control preferences. The reason is twofold. First, the possibility of default alters the pricing schedule of mortgages since lenders need to be compensated for default risk. This endogenously restricts the choice set of households when they buy a house and thereby reduces the temptation that they face in this situation. Second, the possibility of default affects the temptation in the future. Even if they do not choose to give in to this temptation, default is still in the choice set of all mortgage holders. Default will be particularly tempting if the burden of the mortgage payment is very high relative to the utility the agents obtain from their house. The option to default hence has a disciplining effect on how large a mortgage people optimally choose.

2.2 Results of the benchmark model

Figure 3 shows the policy functions for households with high school education at age 30 who enter the period as a renter. The graph shows how much these households save and which LTV ratio they choose as a function of cash-on-hand.[18] Policy functions for the four different degrees of self-control are plotted for comparison. Figure 3, panel A, shows the optimal level of overall savings, that is, the sum of liquid savings and down payment in case the household purchases a house. Overall savings decrease with the problem of self-control. Moreover, for each degree of self-control, there is a particular level of cash-on-hand at which overall savings increase substantially. This is the threshold level of cash-on-hand above which the households purchase a house (and makes a down payment) and below which they remain renters. The figure shows that the stronger the problem of self-control, the higher this threshold for purchasing a house. Note also that even though savings are always lower for stronger problems of self-control, this difference is particularly pronounced in the region between the thresholds, that is, where agents with lower self-control costs already purchase a house while agents with stronger problems keep renting.

Figure 3, panel B, depicts the optimal LTV ratio when buying a house. The optimal leverage increases with problems of self-control. Making a down payment is more costly for households with costs of self-control, and they hence optimally postpone payment into the future.

While the policy functions are important for understanding the effects of self-control, simulation results show the economic relevance of the effects. Table 3, panel A, shows the quantitative effects of the problem of self-control in the benchmark model. The first two columns refer to the welfare effect of self-control problems described above, namely how much better off an agent would be if he was relieved of the costs of self-control but could not change

[18] The model is solved in normalized terms, that is, all level variables are normalized by permanent income. The graph hence depicts both overall savings and cash-on-hand in normalized terms.

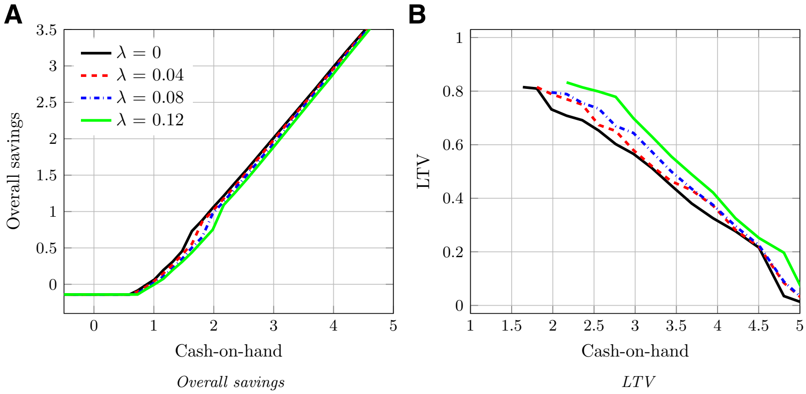

Figure 3
Policy functions in the benchmark model
Policy functions of a high school graduate at age 30 who enters the period as a renter in the benchmark model. The figure plots (panel A) overall savings (= liquid savings + down payment if applicable) and (panel B) LTV as a function of cash-on-hand. Overall savings and cash-on-hand are normalized by permanent income.

his behavior (CE1) and if he could also revise his behavior (CE2). For the large costs of self-control ($\lambda = 0.12$), for example, the welfare increase if the agent was relieved of his problems of self-control would be equivalent to an increase in consumption and housing services of 3.24% in each period. If he was allowed to revise his choices, his welfare would increase by an equivalent of 4.03%. While these welfare effects of self-control are sizable, they are not unreasonably large.[19]

Columns 3–8 give the effects of self-control on the simulated behavior of the households relative to the behavior of the standard agent. These effects have been constructed by simulating the model separately for each degree of self-control. First, I simulate 10,000 households assuming that all households are standard agents ($\lambda = 0$). I report the average behavior over the life cycle in the first row. Then I take the same households (same initial wealth, same income shocks) and simulate them again where the only difference is that now all households have either $\lambda = 0.04$, $\lambda = 0.08$, or $\lambda = 0.12$. Columns 3–8 show the mean individual difference between these simulations and the one for standard agents.

Column 3 shows that the overall net worth decreases with the degree of the self-control problem. For example, agents with low costs of self-control ($\lambda = 0.04$) have on average about US$8,000 less net worth than standard agents during their working life. For households with large costs ($\lambda = 0.12$), this effect increases to a reduction in net worth of almost US$30,000. The differences in optimal savings in the policy functions hence translate into substantial

[19] When judging the magnitudes of these welfare costs, it is important to keep in mind that households in this framework optimize fully given their preferences; that is, they do not make any mistakes. Nevertheless, despite the fully optimizing behavior, they suffer these welfare costs due to their problem of self-control.

Table 3
Effects of self-control in simulation

	Welfare costs of self-control		Effects of self-control on behavior						Welfare effect of policy
	CE1	CE2	Net worth (all)	CC debt rate	Owner-ship (all)	House value (owners)	LTV (owners)	HELOC (owners)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Benchmark model									
$\lambda=0$			70.23	0.13	0.79	121.78	0.39	3.19	
$\lambda=0.04$	1.44	1.49	−8.15	0.07	−0.04	−1.70	0.06	−0.02	
$\lambda=0.08$	2.56	2.85	−17.57	0.17	−0.09	−3.10	0.13	−0.13	
$\lambda=0.12$	3.24	4.03	−29.46	0.31	−0.17	−5.14	0.21	−0.32	
B. Down payment ≥20%									
$\lambda=0$			69.72	0.13	0.74	121.10	0.36	3.16	−0.07
$\lambda=0.04$	1.34	1.37	−7.89	0.07	−0.02	−1.56	0.06	−0.14	0.05
$\lambda=0.08$	2.38	2.61	−16.87	0.16	−0.06	−3.27	0.12	−0.29	0.16
$\lambda=0.12$	3.06	3.70	−27.11	0.28	−0.12	−5.06	0.20	−0.44	0.24
C. No refinancing									
$\lambda=0$			68.73	0.14	0.75	119.87	0.43	1.09	−0.29
$\lambda=0.04$	1.09	1.13	−4.68	0.06	−0.02	−2.46	−0.01	0.70	0.07
$\lambda=0.08$	1.97	2.15	−9.35	0.13	−0.04	−5.35	−0.01	1.53	0.38
$\lambda=0.12$	2.65	3.07	−14.21	0.22	−0.07	−8.47	−0.02	2.44	0.62

Definitions: *Welfare Costs of self-control: CE1*: how much better off would you be if you were relieved of your self-control problem but were not allowed to change your choices?; *CE2*: how much better off would you be if you were relieved of your self-control problem and could change your choices?; both CE1 and CE2 are expressed in terms of each period's percentage increase in consumption of nondurable goods and housing services; *Effects of self-control on behavior*: the values for $\lambda=0$ give the average behavior over the working life for households without costs of self-control, the values for $\lambda>0$ give the mean difference in individual behavior if degree of self-control is changed from $\lambda=0$ (standard agent) to the respective degree of self-control, all else equal; *Welfare effect of policy*: welfare consequences of policies in terms of consumption equivalent, that is, percentage change in consumption of nondurable goods and housing services in each period (without changing the costs of self-control) that would make the agent as well off in the benchmark model as under the implemented policy.

differences in average net worth. Column 4 further shows that agents with problems of self-control hold on average US$310 more in credit card debt than standard agents (in relative terms they hold 2.4 times the credit card debt of standard agents).

Next, in column 5, the ownership rate decreases with the problem of self-control. The average homeownership rate over all working age groups decreases by 4 percentage points for low costs of self-control and by 17 percentage points for large costs. These quantitatively large effects are a combination of the higher threshold for purchase and lower savings, which make any threshold harder to reach. For some households, this means that they never become homeowners, while others become homeowners at a later age. Figure 4, panel A, shows this graphically by plotting the ownership rate over the life cycle by self-control type. It shows that with increasing problems of self-control households postpone becoming homeowners so that the gap is substantial for the young and middle-aged but closes somewhat late in working life.

Columns 6 and 7 refer to the effects of self-control on the housing and mortgage portfolio. House values are on average between US$1,700 and US$5,000 lower for agents with costs of self-control than for standard agents.

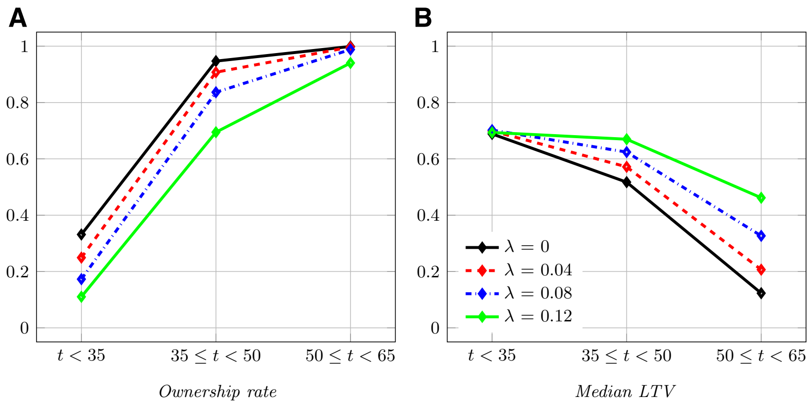

Figure 4
Simulated life-cycle profiles by self-control type
Simulated life-cycle profiles for each of the four self-control types. Panel A shows the ownership rate by age group; panel B shows the median LTV ratio (given owner) by age group.

Furthermore, agents with problems of self-control have between 6 and 21 percentage points higher LTV ratios. This is both driven by the fact that the optimal LTV ratio is higher for a given level of wealth and by the fact that agents with problems of self-control only reach their threshold for purchasing a house later in life. This latter effect reinforces the first since the LTV ratio is highest right after a mortgage is taken out. This can also be seen in Figure 4, panel B, where the median LTV ratio of homeowners by age group is plotted for the different self-control types. The differences are largest in the oldest age group, where standard agents have almost finished repaying their mortgage but people with problems of self-control still have substantial mortgage balances. At the same time, agents with problems of self-control hold fewer HELOCs (column 8). This is the consequence of the higher LTV ratios: they have less available home equity to extract through this channel.

How do these results compare to financial portfolios in micro data? Table 4, panel A, shows conditional correlations of overall net worth, homeownership, house value and LTV ratio with indicators for being a smoker or being obese in the Panel Study of Income Dynamics (PSID).[20] While smokers and the obese are likely to differ along many dimensions from other households (not all of which can be controlled for), column 5 shows that they are more likely to report a stronger problem of self-control in the HRS module discussed earlier. These correlations do not constitute a test of the model. Nevertheless, it is reassuring that the empirical correlations of the financial portfolio variables with smoking and being obese in the cross-section are qualitatively in line with the simulated model outcomes from Table 3. Table 4, panel B, further

[20] For details about this empirical analysis, see Appendix D.

Table 4
Empirical Conditional Correlations

	(1) Log(net worth)	(2) Owner	(3) Log(house value)	(4) LTV	(5) Problem of self-control
A. Correlations in the cross-section					
Smoke	−0.583***	−0.081***	−0.261***	0.001	0.102**
	(0.222)	(0.015)	(0.041)	(0.014)	(0.041)
Obese	−0.767***	−0.019	−0.151***	0.070***	0.112**
	(0.211)	(0.014)	(0.034)	(0.012)	(0.043)
Data set	PSID	PSID	PSID	PSID	HRS
Observations	3,853	3,853	2,802	2,714	1,229
R^2	0.211	0.298	0.277	0.325	0.077
B. Time until first purchase & correlations at first purchase					
Smoke		−0.217***	−0.200***	−0.044	
		(0.073)	(0.058)	(0.027)	
Obese		0.106	−0.055	0.052**	
		(0.067)	(0.054)	(0.026)	
Observations		5,162	781	699	
Households		1,008			
Model		Cox	OLS	Tobit	
R^2			0.270		

Standard errors are in parentheses. Panel A: conditional correlations of financial portfolio variables and the self-control measure with smoking and being obese in the cross-section, obtained by OLS with additional control variables: columns 1–4 (PSID): quadratic term in age, marital status, race, education, family size, health status, and log(income); column 5 (HRS): quadratic term in age, gender, marital status, race, education, retirement status and log(income). Panel B: column 2 estimates the hazard of becoming a first-time homeowner through a Cox proportional hazard model, stratified by cohort, with the following control variables: initial marital status, race, education, family size, and log(income); columns 3 and 4 show correlations with house value and LTV at time of first purchase; control variables: quadratic in age, education, marriage status, race, log(income), and year dummies; the Tobit model is estimated with a lower bound of zero. *Source:* Columns 1-4: Panel Study of Income Dynamics (PSID); column 5: Health and Retirement Study (HRS); and own calculations. $^* p<.1$; $^{**} p<.05$; $^{***} p<.01$.

investigates the predictions from the policy functions. Column 2 details the results from a Cox proportional hazard model, which estimates the hazard of becoming a first-time homeowner.[21] All else equal, smokers have a significantly lower hazard of becoming homeowners. Moreover, columns 3 and 4 look at the portfolio choice at first home purchase: smokers on average have lower house values, and being obese is significantly correlated with higher LTVs. Thus, while they cannot make any causal claims, the correlations in micro data are consistent with both the simulated outcomes and the policy functions obtained from the structural model.

2.3 Increase in minimum down payment restriction

The first policy experiment is to increase the minimum down payment restriction from its benchmark value of 3.5% to 20%. For a standard agent,

21 In this estimation, households enter the sample at age 23 and are followed until first home purchase; time effects are captured by stratifying the model by birth cohort. For details see Appendix D. This appendix further contains the results from a nonparametric estimation of the survival rates by smoking status, which confirms the finding that smokers on average buy houses later in life.

this has only one consequence: it reduces his choice set. A standard agent can hence never be better off due to this restriction. On the contrary, for agents who suffer from the costs of self-control, this is not the only effect. Restricting the choice set also reduces the temptation they face. With a very low minimum down payment requirement, they could afford to buy a large house with a small down payment, which is tempting. Resisting this temptation is costly. If the minimum down payment is increased, the temptation that they face is reduced in each period that they consider buying a house or want to up- or downsize. Moreover, since the LTV restriction also directly affects the share of home equity that can be extracted through HELOC and by refinancing, increasing the minimum down payment requirement also reduces the temptation to extract home equity. This strengthens the commitment effect of the house. Agents with problems of self-control hence have both positive and negative welfare consequences of a minimum down payment restriction. Ex ante it is not clear if the agents will be better or worse off.

Table 3, panel B, shows the effects of self-control on the simulated behavior under the policy of 20% down payment requirement. Relative to the benchmark model, the negative effect of costs of self-control on homeownership is now smaller: The ownership rate of people with problems of self-control is only up to 12 percentage points lower than the ownership rate of standard agents (compared to 17 percentage points in the benchmark model). The table also shows that this translates into a slightly less negative effect of costs of self-control on overall net worth, while the effects on the housing and leverage position are of comparable magnitude as in the benchmark simulation. The one exception is that agents with problems of self-control now hold fewer HELOCs compared to the benchmark case. This is the direct consequence of the tighter combined LTV limit, which reduces the available amount of home equity that can be extracted for a given level of mortgage.

Turning to the welfare consequences of the policy, the results are shown in column 9. The welfare effects are expressed in consumption equivalent terms, that is, the percentage increase in consumption and housing services that would make agents in the benchmark scenario as well off as agents under the policy. Note, however, that all analyses in this paper are of partial equilibrium nature: while households and mortgage lenders react to policy changes (and the mortgage market clears through adjusting the equilibrium mortgage pricing schedule), the house price does not react. All welfare statements therefore need to be understood as welfare consequences holding the house price fixed.

The first thing we note is that the higher down payment requirement is welfare decreasing for standard agents. This is to be expected since for them the only effect of the policy is a reduction in their choice set. Agents with problems of self-control, however, are better off with the higher down payment requirement by an equivalent of consumption increase of up to 0.24%. This implies that the reduction in temptation outweighs the downside of having to pay more of

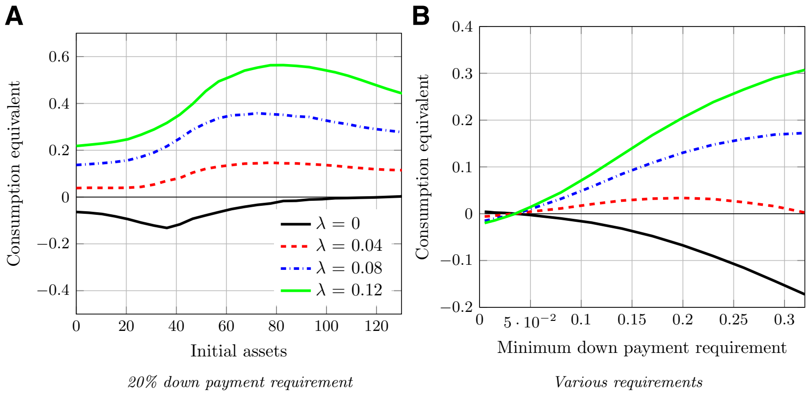

Figure 5
Welfare effect of a change in minimum down payment requirement
Welfare effect of a change in minimum down payment from 3.5% to 20% (panel A) and various down payments (panel B). Welfare effects are expressed as consumption equivalents, that is, percentage changes in consumption of nondurable goods and housing services in each period (without changing the costs of self-control) that would make the agent as well off in the benchmark model as under the implemented policy.

the purchase price upfront.[22] Regarding the magnitude of this welfare gain, it is instructive to compare it to the overall welfare costs of having a problem of self-control in the benchmark model (Table 3, panel A, column 2): in this partial equilibrium setup, the rather crude instrument of increasing the down payment requirement alleviates up to 6% of the overall welfare costs of having problems of self-control.

Figure 5, panel A, breaks down the welfare effect of the increase in minimum down payment against the level of assets agents hold at the beginning of their working life. There is heterogeneity in the welfare consequences between different asset levels. For the standard agent, the policy is more welfare decreasing for lower levels of assets. The reason is that it is now harder for the agents to buy a house and they have to postpone its purchase. For richer standard agents, however, this effect is smaller since they can afford the down payment under either down payment requirement. On the other hand, agents with problems of self-control are better off with the increased down payment requirement at all asset levels. Increasing the minimum down payment requirement reduces the temptation that households face anytime they think about buying a house. For low asset levels, this is the main source of benefit early in their life. Once they buy a house, they benefit from the increased commitment effect of the house. This is particularly beneficial to wealthier households that benefit earlier from the commitment.

22 This welfare gain is naturally influenced by the flexibility of the choice set, where households have several margins they can adjust in reaction to the policy change. For an analysis with less flexibility in reactions and, in fact, qualitatively different welfare results, see Ghent [2015].

While the focus of this section has been on an increase of the down payment requirement from from 3.5% to 20%, Figure 5, panel B, computes the consumption equivalent for several down payment requirements, varying from 0.005% to 32%. In this partial equilibrium setup, households without costs of self-control are best off if the down payment requirement is as small as possible, even if the gains in welfare compared to the benchmark of 3.5% are small (up to 0.004%). At the same time, people with problems of self-control are better off if the down payment requirement is increased and are worse off if it is lowered below the benchmark of 3.5%. Note, however, that the welfare losses due to the lowering of the down payment are relatively small. The reason for this is that the choice set of the households, and hence the temptation that they face, is not enlarged by as much as one might think. Lenders are now allowed to ask for lower down payments—but through their endogenous pricing they will charge higher prices for these riskier loans. Equilibrium mortgage pricing thus endogenously limits the choice set of households and prevents households from buying houses that they will never be able to afford. This reduces the temptation they need to resist when they buy a house and hence limits the welfare losses from the reduced down payment requirement.

To summarize, a down payment requirement of 20% increases the likelihood for people with problems of self-control to become homeowners since the house is now a stronger commitment device. However, the welfare consequences of this policy (holding the house price fixed) depend on the degree of the problem of self-control of agents. While standard agents are worse off if the down payment requirement is increased, agents with problems of self-control benefit from the restriction. These benefits are stronger for wealthier households.

2.4 Possibility to refinance

The second policy experiment is to remove the possibility to prepay and hence to refinance mortgages. In this case, home equity becomes more illiquid since most of it can only be accessed by selling the house, which takes time. While households are still able to extract home equity through HELOCs, the amount that can be borrowed in this way is limited through the PTI constraint. The PTI regulates that the sum of mortgage payments and the total amount of HELOC borrowing (since it is in the form of a one-period bond that needs to be repaid each period) cannot exceed 43% of income. As home equity increases through amortization of the mortgage the PTI constraint hence becomes increasingly binding over the term of the mortgage and makes home equity increasingly illiquid.

For standard agents, the effect of this change is again unambiguous. Their choice set is reduced so that they can never be better off. As before, for agents with a problem of self-control, this is not the only effect. While they also suffer from losing the possibility to easily adjust their leverage, they at the same time benefit from the strengthened commitment effect of both the house and the mortgage. They can save in the form of home equity without ever being tempted to spend a large part of these savings. Moreover, as long as default is not tempting, they can also make mortgage payments without exercising self-control. Ex ante it is not clear which of these opposing welfare effects will dominate.

Table 3, panel C, shows the effects of the policy on the simulated behavior. Column 4 shows that the negative effect of costs of self-control on homeownership is now much smaller: agents with problems of self-control are only up to 7 percentage points less likely to be a homeowner (compared to 17 percentage points in the benchmark model). This is because from the anticipation effects point of view the house is now a stronger commitment device and hence more attractive. This partly counteracts the impatience effect, which still makes it costly to give up current consumption in favor of a down payment. Looking at column 3, we see that this increased commitment nature also strongly reduces the negative effects on overall net worth. In the benchmark model, agents with large costs of self-control had on average almost US$30,000 less overall net worth. Under the no refinancing policy, however, this difference reduces to only US$14,200. Moreover, we see that now the LTV ratio is slightly decreasing with problems of self-control. The reason is the following: in order to use the mortgage as a commitment device, they need to ensure that default will not be tempting. This reduces the size of optimal mortgage payment for a given house size and hence the optimal LTV ratio. At the same time, however, the average amount of home equity extracted through HELOCs is now higher for agents with problems of self-control. The lower LTV ratio on the mortgage leaves more funds available to extract through HELOCs, and resisting the temptation to extract those is costly.

Turning to the welfare effect of restricting the option to extract home equity through refinancing, column 9 documents that the effects again depend on the degree of self-control. Unsurprisingly, standard agents are worse off under the policy since the only effect for them is the loss of flexibility. However, for people with problems of self-control, the gain of the commitment device outweighs the loss of flexibility. People with strong problems of self-control are better off by an equivalent of 0.62% of lifetime consumption. This implies that in this partial equilibrium setup 15% of the overall welfare costs of having a problem of self-control can be alleviated through this policy experiment (compare to Table 3, panel A, column 2). Figure 6 depicts these welfare effects for different levels of initial assets at the beginning of working life. The effects become more pronounced for higher levels of wealth. This is because wealthier households are more likely to become homeowners and hence to get access to the commitment device. Moreover, wealthier households want to save more, so having a commitment device becomes more important.

The exercise in this section compared a setup with strictly no refinancing to one where everybody can refinance. Note, however, that if the agents could choose among a menu of mortgage contracts with and without prepayment restrictions, agents with problems of self-control would optimally select into

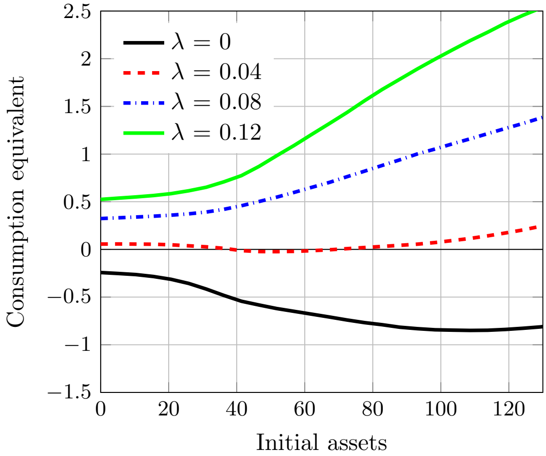

Figure 6
Welfare effect of possibility to refinance
Welfare effect of removing the possibility to refinance. Welfare effects are expressed as consumption equivalents, that is, percentage changes in consumption of nondurable goods and housing services in each period (without changing the costs of self-control) that would make the agent as well off in the benchmark model as under the implemented policy.

the more restrictive product. In this case, people with no or low costs of self-control could continue to take out mortgages with refinancing while people with stronger problems of self-control could benefit from being able to choose a more restrictive option. Currently, prepayment penalties are very limited in the United States due to restrictive mortgage regulations (Consumer Financial Protection Bureau, 2013). However, this is not the case everywhere. In fact, most other developed countries have mortgages with no or only limited prepayment options (Green and Wachter, 2005). The results in this section suggest that giving people the choice between mortgages with and without prepayment penalties has the potential to increase welfare compared to a universal rule that either bans or enforces prepayment penalties for everyone.

3. Conclusion

In this paper, I show that self-control has sizable effects on the housing and mortgage choice and that welfare consequences of financial regulation depend on the degree of self-control, with people with lower self-control tending to benefit from less flexible mortgage contracts. The reason for this finding lies in the dual nature of houses: on the one hand, they are an illiquid investment and as such serve as a commitment device. On the other hand, people also receive utility from their houses. Facilitating access to mortgage credit thus not only increases access to the commitment device but at the same time also increases temptation. The findings in this paper show that depending on the degree of self-control, this increase in temptation has the potential of outweighing the benefits of easier access to houses as a commitment device.

Houses may still be a good commitment device. The findings in this paper merely uncover a tension that should be taken into account when designing policy. Houses can be part of an optimal policy mix, depending on the policy maker's objective function and tool set. Moreover, the results in this paper stem from a partial equilibrium analysis where there is an equilibrium in the mortgage market but the housing market is exogenous. It is therefore not possible to draw direct and final conclusions regarding the optimality of housing as a commitment device or regarding optimal policy.

However, for most households, buying a house and taking out a mortgage are the most important financial decision that they have to make in their lifetime. Recent history has shown that the macroeconomic consequences of failures in the housing and mortgage market can be huge. Regulation of these markets hence plays a crucial role both for the welfare of the individual household and for the economy as a whole. It is important to understand how behavioral biases shape housing and mortgage decisions since this will affect the optimal regulation policies. The present paper is a step in this direction.

Appendix A. Measure of Self-Control in the Health and Retirement Study

The University of Michigan Health and Retirement Study (HRS) is a longitudinal panel study that surveys a sample representative of the U.S. population over the age of 50. It has been running since 1992 and reinterviews the subjects every two years. Over the years, new cohorts are added to keep the sample representative. In each wave, the interview consists of the main interview as well as a set of experimental modules that vary between the waves. While all individuals answer the main questionnaire, each interviewee only answers a subset of these test modules. Wave 2010 contains a test module "Personality" that asks the subjects to assess how much self-control they have. The "Personality" module was answered by 1,254 individuals.

The module asked interviewees to assess their own self-control in various contexts: food, excercise, interpersonal self-control, financial self-control, and general self-control. For the purpose of this paper the questions regarding financial self-control are the most relevant. People were asked to answer on a scale from 1 to 5 how often they do certain things (1: "very often"; 5: "never"):

Spend too much money?
Buy things on impulse?
Buy things you hadn't planned to buy?
Buy things you don't really need?

I follow the designer of the module (Tsukayama, Duckworth, and Kim, 2012) and construct averages of the answers as measures for financial self-control. I reverse the ordering so that a higher level of the measure corresponds to a stronger problem of self-control.

The distribution of this measure is shown in Figure 1 and is used to determine the group sizes of the different self-control types. Furthermore, when comparing empirical correlations with the predictions of the benchmark model, the measure of self-control is used as a dependent variable in an OLS regression on indicators of being a smoker and being obese (Table 4, column 5).

Appendix B. Numerical Solution and Simulation

The model solution is obtained by backwards induction over the value functions, normalized by permanent income (Carroll, 1997). All value functions except when buying a house are solved by discretizing the state space and the control variables. The value function of buying is solved using the simplex method. Expectations are approximated by Gauss-Hermite-Quadrature, and I use linear interpolation to evaluate between grid points.

To approximate the distribution of education in the population, I simulate 15% of the agents with the income process for households without high school, 51% with high school, and 34% with a college degree.[23] The initial distribution of normalized cash-on-hand is approximated by a log-normal distribution for each education group with mean and variance parameters fitted to the net worth-to-income ratio of households with heads aged ≤ 22 ($23 \leq$ age ≤ 25 for college graduates) in the SCF, waves 1989–2004. I adjust the SCF sample to match the wealth distribution of the PSID by dropping the wealthiest 1.47% of weighted observations (17.6% of unweighted observations) (Heathcote, Perri, and Violante, 2010). Moreover, in order to exclude outliers generated by low income, I drop observations with total household noncapital income below the poverty guideline for a family of that size in the given year. Since the number of households with a head of respective education and age is very low in each wave, I combine all waves when fitting the distribution.[24] To obtain the simulated moments, which I match to the data moments, I combine education groups with self-control types, assuming independence between education group and self-control type. Population shares of self-control types were determined based on the measure of self-control in the HRS sample as described in the main text. The shares employed are equal to 25%, 50%, 20%, and 5% (increasing in degree of the problem of self-control).

Appendix C. Mortgage Pricing

Mortgage lenders price mortgages competitively, such that they make zero profits in expectation (Section 1.2.5). Figure C.1 displays an example of the equilibrium mortgage pricing schedule across the three policy scenarios considered in the paper. This is the schedule the mortgage lender is willing to offer to the borrower. It takes into account all constraints and uncertainty that the borrower faces in future periods, but it does not reflect the current loan-to-value or payment-to-income constraints.

For low levels of mortgage size, the price of the mortgage is 1; that is, the mortgage is paid out at face value. As the mortgage size increases, however, the price falls such that less and less of the face value is paid out to the borrower when the mortgage is issued. This is due to the increased default risk. Comparing the pricing schedules across policy scenarios shows that tightening the LTV constraint has a large effect on the pricing schedule, while restricting the option to refinance only alters the schedule to a much smaller extent. The reason is that the LTV constraint directly reduces the loss of the lender in the case of default.

Note that in equilibrium borrowers choose mortgages at a price of 1, which is in line with the observation that they do not default in equilibrium. At the same time, the pricing schedule affects the choice set of borrowers and hence the temptation that they face.

Appendix D. Details about Conditional Correlations in Micro Data

D.1 Correlations in the cross-section

Table 4 shows conditional correlations of financial variables with indicators for smoking and for being obese. Columns 1–4 have been constructed using data from the Panel Study of Income

[23] The percentages were obtained from the Survey of Consumer Finances (SCF), waves 1989–2004.

[24] Fitting a distribution for each wave individually gives a range of parameter values that is similar to the estimates obtained from the pooled sample.

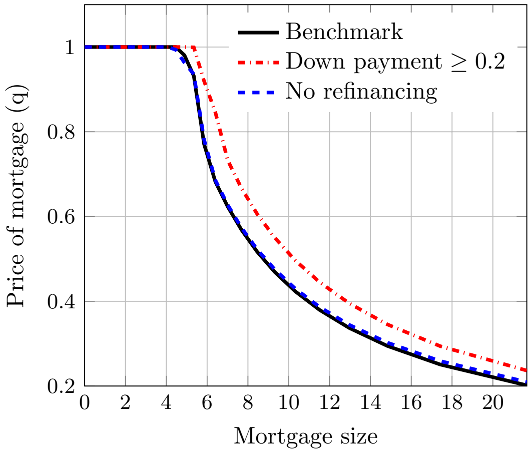

Figure C.1
Mortgage Pricing Schedule
The figure plots an example of the mortgage pricing schedule that borrowers face (borrower characteristics: age 30, high school education, normalized savings –1, normalized house size 5). The figure displays the mortgage schedules for each of the three policy scenarios considered in the paper.

Dynamics (PSID). The PSID is a longitudinal household survey directed by the University of Michigan that has been following families and their descendants since 1968. Until 1997, families were reinterviewed each year and since then are interviewed biannually. At the time of this change, more information has been added to the survey, in particular data about the families' assets and wealth as well as health information.

As is common in the literature, I exclude observations that belong to the Survey of Economic Opportunity (SEO) sample, which was added to the representative sample to increase the information on low-income households. Furthermore, I restrict the sample to families with a male head. The reason is the special way in which PSID determines the head of a household. As soon as there is a male adult living in the household, he is head irrespective of his income or position in the household. Hence, there are not many families with female heads, and this group is a very special subsample. Since there are not enough observations for a separate analysis, I choose to exclude this group. Moreover, I exclude observations missing information in the variables of interest.

Respondents in the survey are directly asked for the value of their house as well as the principal outstanding on the first and second mortgages on that property. I use the sum of the two mortgage principles as the measure for mortgage balance. The loan-to-value ratio (LTV) is computed as mortgage balance divided by house value. The data for total net worth are obtained from the supplemental wealth files. Income is defined as the total household income, that is, the sum of labor income (including from business or farm), pensions (including annuities and veterans' pension), and transfer income (including alimony), for both head and spouse. Obesity is defined according to the classification of the body mass index (BMI).[25] A household is labeled as smoker or obese if at least one of the partners (head or spouse) falls into the respective category.

For the conditional correlations in the cross-section (comparable to results from the simulation of the model), I need to restrict the analysis to one wave. To use information that is as recent as possible while not being affected by the huge disruptions of the housing market, I focus on

25 The exact formula is BMI = mass(kg) / height(m)^2. According to the U.S. Department of Health & Human Services, a person is classified as obese at a BMI $\geq$30.

Table D.1
Descriptive statistics in PSID sample, cross-section 2005

	All obs (%)		Homeowners (%)	
Smoker	29.64		24.52	
Obese	47.81		47.82	
Married	81.00		89.65	
Black	6.13		4.03	
Education				
No high school	10.51		8.57	
High school	56.24		54.43	
College	33.25		37.01	
Self-assessed health				
Excellent	16.32		15.88	
Very good	31.33		31.33	
Good	34.39		35.47	
Fair	13.11		12.67	
Poor	4.85		4.64	
	Mean	Std. dev.	Mean	Std. dev.
Age	45.30	15.61	48.17	14.88
Net worth	307.91	1111.02	400.41	1276.37
Income	67.97	95.78	79.02	108.52
Ownership rate	73.99			
House value			217.33	229.87
LTV			44.77	35.56
Observations	3,853		2,802	

Income, net worth, and house value are expressed in Tsd USD; ownership rate and LTV are expressed in percentage. *Source:* Panel Study of Income Dynamics (PSID), wave 2005, and own calculations.

wave 2005. The final sample for this analysis consists of 3,853 observations, of which 2,802 are homeowners (and 2,714 have information about the mortgage balance). Table D.1 shows the descriptive statistics for the dependent, explanatory, and control variables in this sample.

Several robustness checks have been conducted. First, the results are robust to changing the wave of analysis. Second, the results hold for alternative definitions of the behavioral variables: (a) BMI as continuous variable and (b) “number of partners who are smokers (obese)” as opposed to “at least one partner is a smoker (obese).” In fact, the magnitudes of the correlations increase with the number of partners showing the behavior. Third, I included additional controls such as the economic situation of the parents and state dummies to control for regional effects. Lastly, I controlled for the average income over the last six years instead of current income. The results are robust to all these changes.

The results shown in Table 4, column 5, are based on data from the HRS test module described in Appendix A. The descriptive statistics for the control variables included in the regression are shown in Table D.2. Note that since the HRS sample is much older than the PSID sample (the HRS sample is meant to be representative of people close to or already in retirement), the indicator for smoking has been redefined to reflect this. For the analysis based on HRS data, it is set to indicate whether a person has ever smoked or not.

D.2 Time until first purchase & correlations at first purchase

In panel B of Table 4 in the main text, I analyze the time until first home purchase and the house value and LTV at first home purchase. To do so, I use the PSID data set to build a panel data set where households enter the sample in the year they are 23 years old, and I follow them until they buy their first home or until they drop out of the survey (either through attrition or if they are still renters in the most recent wave). I exclude households who did not report mortgage information in the year they bought a house to avoid nonrandom missing values. Since information about smoking and obesity is only available from 1997 onwards, I label a household as smoker or obese if at

Table D.2
Descriptive statistics in HRS sample

	%	
Has smoked/smokes	55.61	
Obese	30.83	
Male	36.40	
Married	60.21	
High school	54.48	
College	23.33	
Black	14.37	
Hispanic	8.31	
Retired	33.90	
	Mean	Std. dev.
Age	69.76	10.16
Income	61.96	79.51
Observations	1,239	

Income is expressed in Tsd USD. *Source:* Health and Retirement Study (HRS), wave 2010, and own calculations.

Table D.3
Descriptive statistics in PSID sample, panel for survival analysis

	At entry (%)		At purchase (%)	
Smoker	70.24		69.78	
Obese	41.96		44.05	
Married	58.63		86.43	
Black	7.64		5.51	
Education				
No high school	8.63		6.53	
High school	70.63		63.89	
College	20.73		29.58	
	Mean	Std. dev.	Mean	Std. dev.
Age	23.00	0.00	28.85	5.16
Income	29.38	16.83	55.80	36.53
House value			104.59	78.34
LTV			71.27	31.20
Observations	1,008		781	

Income, net worth and house value are expressed in Tsd USD; ownership rate and LTV are expressed in percent. *Source:* Panel Study of Income Dynamics (PSID), wave 2005, and own calculations.

least one of the partners in at least one of the waves since 1997 indicated that he/she is smoking or obese, respectively. Overall, the sample consists of 1,008 households that are followed for a total of 5,162 periods. Table D.3 shows descriptive statistics for the control variables, both for the survival analysis (control variables at entry into the sample at age 23) and for the portfolio choice at purchase (contemporaneous control variables). Note that the PSID did not collect mortgage information in the waves 1973–1975 and 1982. For households who buy a house in these years, I therefore cannot analyze their LTV choice. However, I choose to include those households in the analysis of the purchasing decision as well as the house value since the missing mortgage information is due to survey design and therefore unrelated to any of the regressors.

The hazard of becoming a homeowner is estimated by a Cox proportional hazard model. Since households enter the sample in different calendar years (depending on the year they are 23), they are exposed to varying aggregate conditions in the form of varying housing markets as well as credit markets. To allow aggregate effects to affect households differently at different ages, I estimate

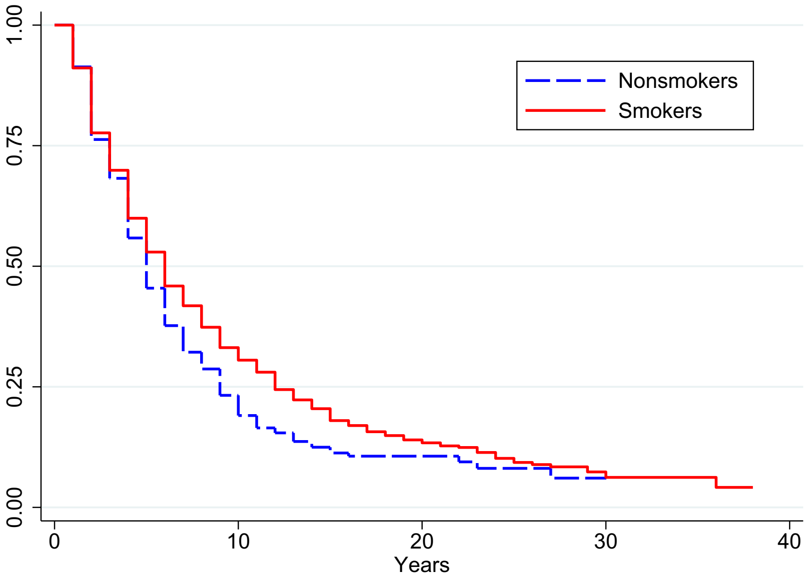

Figure D.1
Nonparametric estimates of the survival function
Kaplan-Meier estimate of the survival function, separate for smokers and nonsmokers. Survival refers to the state of still being a renter: households enter the analysis at age 23 (years = 0) and the plot displays the nonparametric estimates for the fraction of remaining renters over time.

the model stratified by entry cohort.[26] Control variables are fixed at their values at the moment the household enters the study. Figure D.1 further plots a nonparametric estimate of the survival function by smoking status using the Kaplan-Meier estimator. The result confirms that smokers on average become homeowners later in life.

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[26] This specification allows for a different baseline hazard function for each entry cohort that flexibly captures aggregate time effects.

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