Mortgage Loans, the Decline of the Household Saving Rate and the Increase in Risk-Sharing*

Heng Chen[†]and Christoph Winter [‡]

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Abstract

Between 1980 and the beginning of the current century, the U.S. economy experienced: (i) a sharp decline in the personal saving rate, which was associated with a consumption boom, (ii) an increase in mortgage debt, (iii) a rise in the homeownership rate and (iv) an improvement in risk-sharing. In this paper, we analyze to what extent the deregulation of housing finance - i.e., the increased availability of refinancing opportunities and the decrease of effective downpayment requirements -accounts for these trends. To study the impact of the financial deregulation, we implement housing and mortgage loans in an otherwise standard quantitative life-cycle model. The model is consistent with the increase in both net mortgage debt and the homeownership rate observed in the data; it delivers one third of the increase in the ratio of consumption to personal income. Refinancing provides an additional risk-sharing channel by making housing wealth more liquid. As a consequence, households reduce their precautionary saving, take out more collateralized loans and increase both housing and nonhousing consumption. We find that lower downpayment requirements only amplify the effects of refinancing but they do not cause the observed changes in the aggregate trends.

Key words: Mortgage Loans, Financial Deregulation, Risk-Sharing, Household Consumption and Saving, Incomplete Markets

JEL classification: E2, D5, D9

[†]University of Zurich, Institute for Empirical Research in Economics, Office MUB-H 501, Mühlebachstrasse 86, 8008 Zurich (Switzerland), +41 (0)44 634 328, hengchen@iew.uzh.ch

[‡]University of Zurich, Institute for Empirical Research in Economics, Office MUB-G 405, Mühlebachstrasse 86, 8008 Zurich (Switzerland), +41 (0)44 634 52 66, chwinter@iew.uzh.ch

1   Introduction

Between 1980 and the beginning of the twenty-first century, the U.S. economy experienced and 7 percentage point decline in the personal saving rate, and an increase in the consumption share of personal income by 5.5 percentage points. Moreover, the homeownership rate rose by 6 percentage points, while household collateralized debt increased substantially as well.

At the same time, mortgage financing in the U.S. has undergone substantial changes. As we will document later in this study, until the beginning of the 1980s, fixed-term, level-payment mortgage loans were basically the only way to finance a home purchase. One of the most important features of these types of contracts is that homeowners had to increase their share of home equity over the contract period. During an era of financial deregulation, financial instruments, which helped homeowners to access to home equity became relatively inexpensive and widespread.

Our paper tries to quantitatively evaluate the impact of the change in housing financing on aggregate consumption, saving rate, debt holdings as well as homeownership rate. Given that home equity is the single largest position in most household's portfolios, and given that the vast majority of homeowners hold mortgage debt, it is plausible that the changes in the mortgage market are responsible for the documented trends.

We find that in total, mortgage market deregulation accounts for roughly one third of the increase in personal consumption share and the substantial increase in mortgage debt. Our model is also consistent with the increase in the homeownership rate that was observed in the U.S. economy. Moreover, we find that refinancing opportunities play a key role in financial liberalization. The low downpayment requirements amplify the effects of refinancing but turn out to be relatively less important.

Our findings are important for the following reasons. Previous literature has not fully examined the extent to which deregulating mortgage markets accounts for the aggregate trends in consumption and saving. Parker (1999) argues that even if financial deregulation is fully responsible for the rise of household debt, its impact would be too small to account for the increase in aggregate household expenditures. On the other hand, Feldstein (2008) argues that the high level of of mortgage refinancing with equity withdrawal is the primary reason for the low U.S. saving rate and the current account deficit. Recent work by Mendoza et al. (2007) provides further support for Feldstein's hypothesis.[1] Against the background of this discussion, our work attempts to evaluate the different hypotheses. Since there is little doubt that the documented substantial trends are at stake in the U.S. economy, our results have important implications for optimal policy design.

We construct a life-cycle model to shed further light on the role of mortgage mar-

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[1]Mendoza et al. (2007) show that that differences in saving across countries that result from differences in financial market development can lead to global imbalances in the magnitude that is currently observed.

ket deregulation that accounts for aggregate trends in the U.S. economy. In our model, households receive utility from consuming housing services and nondurable goods. Home-ownership is endogenous, and housing services can be acquired through owner-occupied housing or on the rental market. Moreover, households are subject to idiosyncratic, labor income earnings risk. The financial market is assumed to be incomplete; households can only self-insure against earnings shocks by saving in a noncontingent bond.

We model mortgage market deregulation by comparing two different mortgage regimes that we take as a stylized representation of the mortgage loan contracts observed in the U.S. economy. In the first regime, homeowners are forced to repay their obligations, irrespective of the income shocks. Thus, we say that this type of contract gives rise to "forced saving"in home equity. Moreover, equity accumulated in the home cannot be accessed for consumption smoothing purposes later. We also define this regime as a "traditional mortgage". The modeling of mortgages resembles the traditional, fixed-term level payment mortgage loan. See also Chambers et al.(2009a, 2009b) and more recently Nakajima and Telyukova (2009) for similar approaches to modeling mortgage loans. In the second regime, homeowners can avoid pre-fixed repayment by periodically refinancing. In other words, homeowners can revise their mortgage payment contract by negotiating payment schedules and/or altering the amount of repayment.[2]

Notice that the key difference between the first and second regime is that in the latter, households are not forced to accumulate equity in their home beyond the initial home equity at purchase (the downpayment requirement).

Moreover, an additional consequence of mortgage market deregulation was the decline in the downpayment requirements. We characterize this aspect of deregulation by using a lower downpayment ratio in the second regime.

In our experiments, we take an economy where only traditional mortgages are available as being representative of the pre-deregulation period (beginning of the 1980s). The situation in the post-deregulation period is approximated by the second mortgage regime with a lower downpayment requirement.

What we label as the second regime has long been the standard choice of modeling housing finance in the literature (See, for example, Díaz and Luengo-Prado 2009, Ia-coviello and Pavan 2009, Fernandez-Villaverde and Krueger 2010, Yang 2009, Li, Liu, and Yao 2009, Kiyotaki, Michaelides, and Nikolov 2007, Hintermaier and Koeniger 2009 and Scoccianti 2009, among others.).

Compared to the previous literature, the advantages of our models are twofold. Firstly, our set-up allows us to show the *net effects* of the refinancing options. Secondly, it helps us decompose the total impact of financial deregulation into changes that result from lower downpayment requirement and changes that occur because mortgage loans became

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[2]Both of these ways of refinancing help homeowners to change the payment flow.

more flexible.[3] The previous literature has shown that lower downpayment requirements lead to more collateralized debt and higher homeownership rate. In addition, we explicitly examined the effect of refinancing opportunities alone on both mortgage debt and homeownership rate.

Our results show that by deregulating mortgage markets (i.e., by moving from regime 1 to regime 2), consumption, debt and homeownership rate increase and as a result savings fall. The driving force is the additional risk-sharing channel provided by the availability of refinancing opportunities.

Since markets are incomplete, the only way for households to *self-insure* against adverse income shocks is by accumulating a noncontingent bond (precautionary saving). This is the case in regime 1 as well as in regime 2. However, in regime 1, households are forced to increase their home equity as the mortgage matures. We show that forced-home-equity-saving actually increases the demand for precautionary saving. Intuitively, forced-home-equity-saving imply additional committed expenditure for all possible states of nature. This mechanism gives homeowners additional incentive to hold more precautionary savings in order to smooth out nonhousing consumption.

However, when mortgage deregulation takes place and mortgage market structure moves from regime 1 to regime 2, homeowners are not forced to build up home equity over time by following the contracted repayment plan. Moreover, homeowners can access home equity they accumulated in the past easily and use home equity to insure themselves against negative income shocks. The demand for precautionary saving decreases. Therefore, resources will be released for nonhousing consumption.

This implies that households can choose to raise more debt. Homeowners can borrow against home equity, when negative income shocks occur. Moreover, anticipating that home equity can be accessed, households are more willing to accumulate housing stock, compared with households in the traditional mortgage regime. That increases the debt holding even further, since more households can borrow and purchase homes. As a result, both the homeownership rate and housing consumption have increased.

All these effects are amplified when the downpayment requirements become less strict as well. It should be noted, however, that our results indicate that removing the forced-home-equity-saving component from the mortgage loan is more relevant for analyzing the effects of financial deregulation than lowering the downpayment requirement.

It is important to notice that we keep house prices constant in our analysis. Thus, the increase in consumption in this model economy does not stem from the "wealth effect." [4] The evidence on the wealth effect is mixed in empirical literature. Carroll et al.

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[3]Starting with the seminal work of Jappelli and Pagano 1994, the previous literature has mainly used the downpayment requirement as a measure for the restrictiveness of mortgage contracts. Consequently, financial liberalization is modeled as an event that leads to lower downpayment requirements (See, for example Iacoviello 2008 or most recently Favilukis et al. 2010 and Scoccianti 2009).

[4]According to the permanent-income hypothesis, consumption adjusts to the unexpected changes in

(2006) estimate that an one-dollar increase in housing wealth raises consumption by about nine cents, while Lettau and Ludvigson (2004) conclude that the marginal propensity to consume out of housing wealth is close to zero.

In this paper, we do not model fluctuation of housing prices and focus on the impact of refinancing opportunities to explain the consumption boom. It is a more important aspect, since homeowners must have access to home equity before they can take advantage of the increased housing value. Indeed, Doms et al. (2008) provide empirical evidence for the fact that the linkage between housing wealth and nonhousing consumption increased after mortgage market deregulation, suggesting that refinancing opportunities play an important role not only for housing consumption, but also for nonhousing consumption.

Hurst and Stafford (2004) provide further empirical evidence in support of our hypothesis by showing that households indeed refinance their mortgage for consumption-smoothing purposes.[5] Their empirical evidence lends direct support for one of the main mechanisms highlighted in our model: mortgage refinancing plays an important role as a consumption smoothing mechanism, besides the use of standard precautionary savings.

Precisely and intuitively, refinancing provides an additional channel of risk-sharing. It allows for state-contingent saving, in the sense that households only save when income shocks are positive. In the presence of adverse income shocks, households could borrow by using their home equity as collateral. In contrast, the traditional mortgage payment plan forces homeowners to save in home equity in all states of nature.

It should be noted that in the refinancing regime, households rely less on the precautionary savings for insurance. Or in other words, they substitute the home-equity risk-sharing channel for the standard precautionary-saving, self-insurance channel. It is not clear if the over all risk-sharing opportunity would improve or not. However, our results indicate that total risk-sharing opportunities for homeowners improve in the refinancing regime.

Similarly, Favilukis et al. (2010) also concluded that housing finance deregulation increases the risk-sharing opportunities in a model with housing production. In their model, they also showed that both lower downpayment ratios and lower transaction costs increase households' access to credit, which helps households to insure better their idiosyncratic risks. However, they focus on the period between 2000 and 2006, where they implicitly assume that refinancing was available. In contrast, we compare the period between 1980 and the beginning of new century, where mortgage refinancing became increasingly popular. Although we also conclude that lowering the effective downpayment ratio helps to increase risk-sharing, we highlight that the change in mortgage structure alone played a major role in increasing risk-sharing opportunities.

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housing wealth induced by changes in housing prices.

[5]Previously, the housing literature mainly focused on the "financial motivation"of mortgage refinancing. And house price and mortgage rate changes were considered to be the main driver for refinancing activities.

Hryshko et al. (2009) argue that house prices appreciation helped homeowners to extend their borrowing capacities because the value of their collateral has increased. We assume that housing prices are constant and stress that the availability of refinancing itself can provide sizable increase in risk-sharing opportunity, even when housing prices do not change. It should be noted that increasing house prices can only provide better risk-sharing in combination with better opportunities to access home equity. Otherwise, homeowners do not benefit from changes in their housing wealth.

Thus, our paper also contributes to the literature that argues that risk-sharing opportunities have improved over the last decades. Krueger and Perri (2006), for example, argued that the decoupling between income and consumption inequality points to the fact that market completeness, i.e. the ability of private financial markets to insure risks, has improved over time. We propose a specific channel through which financial markets could have provided better risk-sharing opportunities and quantify its relevance. In another important contribution, Heathcote et al. (2008) depart from the bachelor model of household formation and argue that risk-sharing within the couple can explain the decoupling between earnings and consumption inequality. We view their explanation as complementary to ours.

The rest of the paper is comprised of the following sections: In the section 2, we document the substantial changes in the U.S. housing market over the last decades, as well as the institutional background for the changes. We also present evidence of the decline in saving rates, the consumption boom and the increase in debt during that period. Section 3 presents a simple life-cycle model with analytical solutions. It shows the main mechanisms, by which the refinancing opportunities affect the saving rate and risk-sharing among households. Section 4 outlines quantitative models that compare the two regimes. Section 5 details the calibration strategy and discusses the main results. Section 6 concludes with recommendations for possible future research.

2 Institutional Background: Deregulation, Mortgage Debt, and Saving Rate from 1980-2000

In this section, we first outline the institutional origins of what is commonly called "traditional mortgages", i.e. long-term amortized mortgages that require the mortgagee to take an initial equity share at the time of purchase and to accumulate further equity as the debt amortizes (typically over a period of 15 to 30 years). We then present the emergence and popularity of refinancing opportunities in the last decades.[6] We also document the substantial increase in the household debt holding and the decline in the household saving rate, as well as the associated "consumption boom", during the period from 1980

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[6]We draws heavily on Campbell and Hercowitz(2006,2009) as well as on Gerardi et al. (2006).

to the beginning of the current century in the U.S. economy.

2.1 Origins of the Long-Term Amortized Mortgage Structure

The vast majority of homeowners (about 90%) acquire their homes by using long-term amortized mortgages mortgages, which is considered the "standard" loan product.

Amortized mortgages originated with the New Deal regulations, with particular in the Federal Home Loan Bank Act of 1932 and the Home Owners' Loan Act of 1933. These regulations reflected the desire of the Roosevelt administration to reduce the likelihood of a mass default, which occurred at the beginning of the Great Depression (Campbell and Hercowitz 2006 and 2009). In particular, the "forced saving"component of long-term amortized mortgages (i.e., the fact that homeowners were forced to raise their equity in their homes as the loan amortizes) was seen as a way to reduce the possibility of systemic default. Before, interest-only, periodically refinanced mortgages were common, which allowed homeowners to hold a very low equity share in their homes.

Depression-era regulation was also meant to insulate the mortgage market from fluctuations in other financial markets (Campbell and Hercowitz 2006 and 2009). Prior to the 1980s, mortgage loans were almost exclusively issued by thrift institutions (savings and loans). Regulation constrained savings and loans to raise most of their funds needed to issue mortgage loans by using short-term deposits. This is referred to as the "maturity mismatch"problem, as lenders were forced to finance long-term mortgages with short-term liabilities. Moreover, thrift institutions faced usury laws and interest-rate caps ("Regulation Q") which restricted the conditions to which they could borrow and lend (Campbell and Hercowitz 2006 and 2009 and Gerardi et al. 2006).

2.2 Structural Change in the Mortgage Market and the Emergence of Refinancing Opportunities

The high inflation at the end of the 1970's and the beginning of the 1980's made the New Deal financial regulations untenable. The main reason for the failure was the maturity mismatch on the balance sheet of the savings and loans institutions. The fact that savings and loans financed mortgage loans with short-term deposits made mortgage lending unprofitable, because nominal interest rates on mortgages were fixed and relatively low compared to the high, nominal interest rates that were required to attract deposits (Gerardi et al. 2006).

Congress and Presidents Carter and Reagan responded with the Monetary Control Act of 1980 and the Garn-St. Germain Act of 1982. As a result, usury ceilings, interstate banking prohibitions, limits on branching, and Regulation Q, which capped deposit rates and forbade banks from paying interest on checking deposits, were abolished. Moreover,

state laws that constrained the types of mortgage products originators could offer were preempted (Gerardi et al. 2006).

As a result, a process which is often referred to as "financial innovation" began. This has changed the housing finance system dramatically, increasing the menu of mortgages available to homeowners considerably. Lenders now offered borrowers much more flexible repayment schedules.

Instruments for avoiding forced saving already existed before financial deregulation. One could cash-out previously accumulated home equity either by taking a second mortgage or a home-equity loan or by refinancing the debt with a loan exceeding the current mortgage balance. However, lack of competition made these products prohibitively expensive. In contrast, deregulation eliminated legal barriers to entry and was so considerably more competitive (Bennett et al. 2001). In addition to deregulation, advances in information processing technology also helped to lower costs by streamlining the mortgage application process (Bennett et al. 2001).

2.3 Mortgage Refinancing over the Last Decades

After the financial deregulation, refinancing activities have been increasingly popular, and homeowners have been using refinancing as a tool to smooth their consumption when negative income shocks occur.

Using various waves of the SCF (Survey of Consumer Finances), Campbell and Hercowitz (2009) document a sharp increase in refinancing activities after the deregulation (See Table 1.). In 1983, approximately 10 percent of mortgagees had refinanced. By 1989, this number had more than doubled, increasing again to 33 percent in 1992. In 1995, it reached almost 41 percent, and it was slightly higher than that in 1998 and 2001. Campbell and Hercovitz conclude that "mortgage refinancing went from atypical to commonplace in about 12 years"(Campbell and Hercowitz 2009, p.3).[7]

It is important to study the motives of households who refinance. Some may refinance their mortgage for consumption smoothing purposes, while others may simply want to take advantage of lower interest rates.[8] Interest rate movements and expected interest rates movements can explain some of the refinancing activity. However, as noted by Hurst

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[7]Note that the reported numbers are likely to underestimate the true trend of refinancing activities. Campbell and Hercowitz (2009) measure refinancing activities by computing the share of those households for which the year of home purchase does not coincide with the year the oldest mortgage debt was issued. This identification strategy misses those households who pre-pay (i.e. repay their mortgage loan before maturity) as these households do not take out a new mortgage.

[8]The latter motive, which we call "financial motivation"(Hurst and Stafford 2004), might be particularly important in an environment with volatile inflation rates that prevailed at the beginning of the 1980s. When current mortgage rates are below the existing mortgage contract rate, households have an incentive to replace their existing fixed-rate mortgage with one at a lower rate. The benefit to the household is a present value of wealth gain.

Table 1: Refinancing Activities and Effective Downpayment

Year	Percent of Mortgagees Refinanced	Average Equity/Value at Purchase
1983	9.9	22.6
1989	21.2	23.4
1992	33.0	20.9
1995	40.9	16.9
1998	42.3	16.4
2001	44.4	16.4

Source: From Survey of Consumer Finances
Campbell and Hercowitz (2009)

and Stafford 2004, this explanation cannot account for fact that there is a significant share of mortgagees who refinance, even if interest rates are stable or even rising. Stanton (1995) notes that some fixed-rate mortgages are prepaid even when current market mortgage rates are above the household's contracted coupon rate, and some fixed-rate mortgages are not prepaid even when current market mortgage rates are well below the household's contracted coupon rate. Using the Panel Study of Income Dynamics (PSID), Hurst and Stafford (2004) find that many households refinance after a negative income shock. They conclude that the consumption smoothing motive is essential for understanding refinancing behavior.

Moreover, Campbell and Hercowitz (2009) also provide information about the development of effective downpayment ratios, i.e., ratio of the average equity relative to the value of newly purchased homes. Because of the financial deregulation, borrowers are allowed to take out second and third mortgages easier, and the effective downpayment ratio declines over time. This is indeed the case, as the second column of Table 1 shows.

In summary, the financial deregulation triggered innovations in the mortgage market, which helped an increasing number of homeowners to better access their home equity, both through loan refinancing and lower downpayment ratios.

2.4 Household Debt

Following the financial deregulation, mortgage debt began to grow. Mortgage debt relative to average labor income increased by more than 15 times, if we compare data from the 1983 and the 2004 Survey of Consumer Finances (SCF). In our calculation, mortgage debt includes primary mortgages, home equity loans, home equity lines of credit and labor income including wage income and income from self-employment.

It is interesting to see that mortgage debt grew not only in absolute terms, but also relative to the value of houses: the ratio of mortgage debt to the value of owner-occupied homes was 0.31 in 1982, 0.37 in 1990, and 0.42 in 1995. Since 1995, it has fluctuated

around this higher level (see Campbell and Hercowitz 2009).

During the 1990s, not only mortgage debt, but also financial assets have grown rapidly. This suggests that many households may have used refinancing opportunities to leverage their financial market activities, instead of using these opportunities as a buffer for consumption. We thus also compute the *net debt*, defined as financial assets minus mortgage debt, if the difference is negative. If the households are in negative net financial position, they are net borrowers in this economy. We suspect that net borrowers are more likely to use mortgage debt for the purpose of consumption smoothing. Therefore, this measure is closer to the purpose of our study.

We find that net debt has grown as well, although less dramatic than mortgage debt. The fraction of the population that is in net debt has grown by 7 percentage points, and net financial debt relative to average labor income has grown from 123% to 160% between 1983 and 2004. This result can be interpreted as the average mortgage position in the economy.[9] Our definitions of debt, assets and income follow those used by Kennickell et al. in the SCF bulletin.[10]

These findings provide further evidence of the fact that mortgage debt rose and that it was increasingly used to finance consumption, either in form of housing services or in form of nonhousing consumption. As the next section shows, the increase in (net) debt indeed coincided with a rise in aggregate consumption.

2.5 The Decline in Household Saving Rate and the Consumption Boom

The U.S. economy experienced a decline in the household saving rate in the past decades. There are different definitions of household saving rate; however the decline is quite robust regardless of the definitions. For example, the *private saving rate* was at its post-1950 average level of 17.6 percent as recently as 1993, but it dropped to 13.1 percent at the very end of 1990's, reaching its lowest level in nearly 50 years.

At the meantime, it witnessed an even more dramatic decrease in the *personal saving rate*. Guidolin and Jeunesse (2007) document this change and argue that the decline in the personal saving rate is a very robust fact, despite measurement issues.[11] According to NIPA, it has dropped from 9.8 percent in the 1980 to roughly 2.9 in the 2000.

Although a wealth of evidence shows household saving rate declines substantially, National Income and Product Account (NIPA) definitions of saving rates do not directly

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[9]Notice, however, that our measure of income does not correspond to GDP.

[10]It should be noted that the 1983 is only partially comparable with the other SCF waves because of a change in sample design and in the questionnaire.

[11]Personal savings is defined as one minus the ratio of personal outlays to disposable income. Personal outlays is the sum of the consumption expenditures plus interest paid by persons and personal transfer payments abroad.

correspond to the economics concepts, as Parker (1999) points out. Instead, it is simpler and more useful to exam the other side of the coin, namely the consumption share of national output. Consistent with those findings regarding the saving rate, it is documented that the consumption share of GDP has increased by 6 percentage points from 1980 to 2000. This increase itself is striking and seems even more pronounced by comparing the period from 1950 to 1980 where the consumption-GDP ratio was roughly constant. NIPA also shows that personal consumption expenditure accounted for 87.7% of personal disposable income in 1980 and the ratio has increased to 93.2% in 2000.

It is also important to note that NIPA data measures a broader definition of consumption, namely consumption expenditure. It includes both consumption (non-durable consumption plus services, including housing services) and durable goods expenditures (excluding housing). The expenditures on durable goods increased only by 0.1% from 1980 to 2000. Obviously, it is not sufficient to explain the consumption boom. On the other hand, data suggest that the share of non-durable consumption plus the services (including housing services) increases substantially. In other words, in order to account for the increase in substantial increase in the consumption share, one must explain why non-durable consumption and services increases substantially.

Even though a consensus of researchers believe that the dramatic decrease in the household saving rate is quite substantial, what has triggered this decline in the saving rate and increase in consumption share has remained a hot issue.

Among alternative explanations (wealth effect created by stock market bubbles, change in demographic structure, an increase in the discount rate, etc.), Feldstein (2008) hypothesizes that mortgage refinancing with equity withdrawal is one of the major drivers of the decline in the household saving rate. The consumer's ability to borrow is both enhanced by financial innovations which allow consumers purchase a house with lower downpayment requirements and financial instruments which help homeowners access home equity. In contrast, Parker (1999) is more conservative about this mechanism and argues that the channel alone can only explain a limited part of the increase in consumption share, if any. This paper tries to quantitatively evaluate the impact of financial liberalization on the decline in the saving rate and the consumption boom.

3   Simplified Economy

In the previous section, we outlined the institutional origins of traditional mortgage loans. In particular, we showed that traditional mortgage loans imply that homeowners are forced to accumulate equity as the loan matures ("forced saving"). Moreover, under the traditional mortgage regime, homeowners cannot access the home equity they accumulated in the past ("lock-in effect"). By making use of refinancing opportunities, homeowners can avoid accumulating equity in the first place or they can tap the home

equity they accumulated in the past easier.

In this section, we analyze to what extent refinancing opportunities change the saving choice of homeowners and affect their risk-sharing opportunities. We will demonstrate that precautionary saving under the traditional mortgage regime is higher than that under the refinancing regime. Intuitively, this is because the features of the traditional mortgage contract amplify the impact of earnings uncertainty. We show, however, that, despite the fact that households accumulate more savings for consumption smoothing purposes in the traditional mortgage regime, households enjoy better risk-sharing in the refinancing regime.

Our analysis in this section is based on a simplistic life-cycle model which permits an analytical solution. In the next section, we present a quantitative model that incorporates more realistic life-cycle features and institutional details. That model, however, does not allow for an analytical solution. With the help of numerical methods, we will show that the main conclusions that we derive from this simple model still hold, and more importantly, they are quantitatively relevant.

3.1   Environment

We consider a simple life cycle economy, which is populated by a continuum of ex-ante identical households. Household take the interest rate, r, as given (partial equilibrium).

Each household lives for three periods, $t = 1, 2, 3$. The household receives labor income in the first two periods and pension benefits in the last period. Labor income in the first period, $y_1 = 1$, is deterministic. Income in the second period is uncertain and given by $y_2 = 1 \pm \epsilon$, where positive $(+\epsilon)$ and negative $(-\epsilon)$ shocks occur with the same probability, 0.5. Moreover, shocks are uncorrelated across individuals. Retirement is denoted by y_r, that is, $y_3 = y_r$.

Households receive period utility, $u(c_t, h_t)$, from consuming housing services h_t and nonhousing consumption c_t. We impose the restrictions $c_t > 0$ and $h_t > 0$. Utility is separable across time. Total lifetime utility is thus given by

$$ U = E_0 \sum_{t=1}^{3} \beta^{t-1} u(c_t, h_t). $$

We further assume that period utility is separable across good, i.e., $u(c_t, h_t) = u(c_t) + u(h_t)$. We assume households are risk-averse and prudent, namely, $u'(.) > 0, u''(.) < 0$ and $u'''(.) > 0$. For simplicity, we assume the interest rate $r = 0$ and the discount factor $\beta = 1$.

In this simple economy, we highlight the impact of the traditional mortgage loan structure by making the following assumptions. Households are required to be homeowners. At the beginning of their life cycle, they buy a house of size $\bar{h}$ through a mortgage loan.

Households are not allowed to adjust the size of their housing size over the life cycle. We further assume that the housing stock does not depreciate and can be fully collateralized. Note, that these assumptions are relaxed in the quantitative model. [12]

3.2 Mortgage Loans

A house of size h is financed by a collateralized mortgage loan of size d. When households enter the economy, the mortgage loan is fully collateralized, and the initial mortgage loan is $d_1 = h^*$.

We consider the following two different mortgage regimes:

1. Traditional Mortgage: The bank requires repayment of the mortgage during the first period, and households cannot access their home equity afterwards: $d_t = 0$ if $t \geq 2$. In the following, we will label this regime as "no refinancing (NR)".

2. Refinancing: Households can choose the payment stream, hence $0 \leq d_t \leq h^*$. We will also label this regime as "refinancing (R)".

Regime 1 characterizes the payment requirement of the traditional mortgage loan. Regime 2 instead allows households to choose the payment stream of the mortgage debt. In extreme, households can choose not to repay their mortgage debt until the end of their life. This is possible, since debt is collateralized by the value of the house. That means if the household dies without having repaid the loan fully, the bank obtains the remaining housing equity to cover the mortgage debt.

Since un-collateralized borrowing is not allowed, households accumulate financial assets, $a \geq 0$, for consumption smoothing purpose. For simplicity, we define *net financial assets* $\widetilde{a}_t \equiv a_t - d_t$. We assume that initially, financial wealth is zero, i.e. $a_1 = 0$ and $\widetilde{a}_1 = -d_1$.

3.3 The Household's Problem

We now state the household's maximization problem backwards at each period of the life cycle.

Period 3: We start with the last period (Period 3). The optimization problem reads as follows:

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[12]In quantitative models, households are free to choose their housing consumption (i.e., the exact size of h). There will be transaction costs, so that changing owner-occupied housing is costly. Moreover, households can also decide whether they want to obtain their housing services from owner-occupied housing or by renting. And also the housing stock can only be fully collateralized. We will also relax the assumption regarding the separability of preferences across housing and nonhousing consumption.

$$\max_{c_3} \ u\left(c_3\right) + u\left(h^*\right),$$

$$c_3 + h^* = \widetilde{a}_3 + y_r + h^*,$$

where c_3 is the household's consumption at Period 3. Notice that in the traditional mortgage case, $\widetilde{a}_3^{NR}$ gives both the net and the total financial assets ($\widetilde{a}_3^{NR} = a_3^{NR}$), because $d_3 = 0$. In the refinancing case instead, $\widetilde{a}_3^{R}$ might be negative, as long as $\widetilde{a}_3^{R} \geq -h^*$.

Period 2: In Period 2, household's problem reads,

$$\max_{c_2} \ u\left(c_2\right) + u\left(h^*\right) + u\left(c_3\right) + u\left(h^*\right),$$

$$c_{2,i} + h^* = \widetilde{a}_2 + y_{2,i} - \widetilde{a}_3 + h^*.$$

The second period's income is uncertain, as income shocks can be good ($i = g$ and $y_{2g} = 1 + \epsilon$) or bad ($i = b$ and $y_{2b} = 1 - \epsilon$). The two mortgage regimes imply different constraints for net financial wealth. Under the traditional mortgage regime where homeowners cannot access their home equity, $\widetilde{a}_3^{NR} \geq 0$. In contrast, under the refinancing regime, $\widetilde{a}_3^{R} \geq -h^*$.

Period 1: The household's optimization problem in the first period reads as follows:

$$\max_{c_1} \ u\left(c_1\right) + u\left(h^*\right) + E\left(u\left(c_2\right) + u\left(h^*\right) + u\left(c_3\right) + u\left(h^*\right)\right).$$

such that

$$c_1 + h^* = y_1 - \widetilde{a}_2 + h^* + \widetilde{a}_1.$$

Notice that for simplicity, we assume that y_1 is deterministic. Similarly, the traditional mortgage regime requires $\widetilde{a}_2^{NR} \geq 0$, whereas in the refinancing regime, $\widetilde{a}_2^{R} \geq -h^*$. Recall that the initial holding of financial wealth is zero, i.e. $a_1 = 0$ or $\widetilde{a}_1 = -h^*$ in both regimes.

3.4 Results

We need to make an additional assumption on housing size and income profile to make this problem interesting.

Assumption 1. $y_1 > h^* > y_{2b} + y_1 - y_r.$

This assumption states that the size of the initial mortgage is large relative to the lifetime income that a homeowner receives if the second period's income realization turns

out to be bad. And it is smaller than the income in the first period. This assumption also implies $y_r > y_{2b}$.

With assumption 1, we can show the following result:

Lemma 1. In the traditional mortgage regime, the upper bound on household's saving at the end of period 1 is $\widetilde{a_2}^{NR} < y_r - y_{2b}$.

In other words, this Lemma gives $\widetilde{a_2}^{NR} + y_{2b} < y_r$. It means that in the traditional mortgage regime, if the income realization turns out to be bad, households have incentive to borrow against future income.

Result 1. Homeowners in the traditional mortgage regime will have net financial assets that exceed those of homeowners in the refinancing regime at period 2, $\widetilde{a_2}^{NR} > \widetilde{a_2}^{R}$.

That is, the net financial assets of homeowners at the beginning of the second period are higher in the traditional mortgage regime as compared to the refinancing regime.

This is what we call the "forced-saving effect" of traditional mortgage loans. It is important to notice that it hinges on the Lemma (1). The fact that homeowners in the traditional mortgage regime have an incentive to borrow but cannot cause an excess amount of savings in the first period with respect to the refinancing regime.

With Lemma (1) and Result (1), we show the "lock-in effect". Precisely, since borrowing is not possible at Period 2, optimal consumption choices in Period 2 and 3 are

$$c_{2b}^{NR} = y_{2b} + a_2^{NR},$$

and

$$c_3^{NR} = y_r,$$

In contrast, consumption choices under refinancing regime,

$$c_{2b}^{R} = c_3^{R} = \frac{y_{2b} + y_r + a_2^{R}}{2}.$$

In the traditional regime, consumption in Period 2 and Period 3 do not coincide, if the income shock turns out to be bad. On the other hand, refinancing opportunities allow households to achieve a flat consumption profile, given the negative shock realized in Period 2.

It is interesting to note that although households in the traditional mortgage regime accumulate more net financial wealth than households in the refinancing regime, they do not achieve a smooth consumption profile between Period 2 and Period 3. In other words, households in the refinancing regime save less but the fact that they can access home equity in Period 2 allows them to achieve a smoother consumption stream.

We now show that our findings have important implications for the ability of homeowners to share income risk. We measure the degree of risk-sharing by the dispersion of

consumption across the various income realizations in period 2. In our economy, because utility is concave, perfect risk-sharing would imply that consumption is equal across all states of the income process. That is, the higher the degree of risk-sharing, the lower the dispersion of consumption.[13]

The next result then suggests that risk-sharing is better in the refinancing regime.

Result 2. The dispersion of consumption in Period 2 is greater for homeowners in the traditional mortgage regime compared to the dispersion of consumption in the refinancing regime.

$$c_{2g}^{NR} - c_{2b}^{NR} > c_{2g}^{R} - c_{2b}^{R}.$$

This finding is very interesting. It implies that, despite the fact that homeowners in the traditional mortgage regime accumulate more financial assets than homeowners in the refinancing regime, they actually achieve less risk-sharing. Put differently, when financial markets are deregulated, we would expect to see a decline in saving and a decrease in consumption variability, which is quantitatively consistent with the trends in the U.S. economy. In the next section, we present a quantitative model that allows us to evaluate the quantitative importance of this effect.

4 Quantitative Model

4.1 Households

We consider an economy with one unit mass of finite-lived households, aged from 0 to J. Households face mortality risk along the life span, and the conditional probability of surviving is $\psi_j \in (0, 1)$. The newborn, therefore, survive until age j', with a probability of $\Pi_{j=0}^{j'} \psi_{j+1}$. The population size of households at age j is μ_j.[14]

Each household supplies inelastic labor, $\bar{l}$, each period to the firm in final production sector until retirement age, j^*. Age specific productivity is v_j, which is the mean lognormal income of the j-year old. Additionally households face uninsurable income risks when they work. Individual i's period-specific earning shock is e_{it} at period t. And the law of motion of the earning risk is standard AR(1): $e_{t+1} = \rho \cdot e_t + \varepsilon_t$, where $\rho \in (0, 1)$ is the persistence and ε_t is the white noise with a standard deviation σ_e. A worker's gross labor income in period t and age j, is $w_t \cdot e_t \cdot v_j$, where w_t is the wage rate. Working households pay tax on their gross labor income, and the tax rate is τ_t. Retired households

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[13]In the quantitative model that we present in the next section, we measure the dispersion of consumption by variance of the percentage deviation of consumption from its mean.

[14]We assume households do not have bequest motives and leave remaining net worth as "terminal consumption", e.g. funeral and medical expenses (Favilukis et al. (2010)).

receive a pension benefit, p, from the government. Therefore, the labor or pension income for household i in period t is $y_{i,t}$, and

$$y_{i,t} = \begin{cases} (1-\tau) \cdot w_t \cdot e_{it} \cdot v_j \cdot \bar{l} & j < j^* \\ p & j \geq j^*. \end{cases}$$

Another source of income for households is the return of their financial assets, a. The interest rate in this economy is r_t at period t, and the gross return is $(1+r)$.

Households value the consumption of a nondurable goods and housing services that can be obtained on the rental market or through home ownership. Precisely, households derive period utility, $u(c, h^s)$, from two types of consumption: non-durable consumption goods, c, and housing services, h^s. Households can either consume housing services by rental a house (of size f) from the renting market, or housing service provided by their own housing stock, h,

$$h^s = z \cdot h + (1 - z) \cdot f,$$

where z is an index function, taking value 1 and 0: $z = 1$ for households being homeowners and $z = 0$ for being renters. Moreover, lifetime utility is discounted every period at a rate of $\beta > 0$.

The depreciation rate for homeowner's housing stock is δ_o. And we assume that the homeowners pay $\delta_o \cdot h$ for maintaining their homes[15]. The depreciation rate for renting a house is δ_r.

Households can buy and sell houses in the housing market with transaction costs, which are in proportion to the housing size(s) they sell and/or buy, $tr(h', h)$, and

$$tr(h', h) = (1 - I(h = h')) \cdot (\tau_s \cdot h + \tau_b \cdot h').$$

where τ_s and τ_b are the proportions of transaction fees to the housing values homeowners sell and buy respectively. $I(x)$ is an indicator function, which takes value one if the relation x is true, and zero otherwise.

4.2 Market Arrangement

There are no state-contingent markets for the household-specific shocks and the set of financial assets is exogenously determined. In particular, there is only one financial asset, a bond, which pays interest independent of the realizations of income shocks. Therefore, households cannot fully insure against their idiosyncratic risks. They can only self-insure by saving, using bonds.

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[15]In other words, we assume that homeowners have to maintain all the depreciated part of the housing stock they own.

4.3 Government

The government taxes labor income and redistributes the revenue to the retired. Specifically, the government transfers pension benefit, p , to each retiree, in every period. Labor taxes τ_t are adjusted such that the government's budget is balanced.

4.4 Firm in the Goods Sector

There is one single-good in this economy, which is produced by a representative firm in the goods sector. The production technology is standard Cobb-Douglas,

$$Y = K^\alpha \cdot L^{1-\alpha}$$

where K represents aggregate capital, L aggregate labor demand and Y the output in the goods sector. Aggregate capital depreciates at a rate of δ_k. In this economy, aggregate labor supply is exogenous and determined by the age-specific productivity and the idiosyncratic productivity of households in this whole economy. Since there is no aggregate risk, the aggregate labor supply is constant in this economy.

4.5 Renting Market, Housing Market and Financial Sector

There is a competitive financial intermediary sector with a large number of risk neutral financial firms. Competition among those firms drives profit to zero in equilibrium.

Financial firms collect savings from both foreign and domestic households. We denote the aggregate deposits from domestic households A^d and the aggregate foreign deposits A^f.

Financial firms can transform households' financial assets into productive capital, residential capital and owner-occupied housing stock, on a one-to-one basis without any adjustment costs. Therefore, the relative price between productive capital and housing stock/residental capital, as well as the relative price between productive capital and consumption are always one. K is the capital rented to the representative firm that produces final goods. Residential housing, F, is the total supply in the renting market to the renters. Financial firms also construct owner-occupied homes and sell them to households. Households can also borrow from financial firms, using housing stock as collateral. In other words, financial firms can issue mortgages to homeowners.[16] We denote the aggregate mortgage loan D. Table 2 presents the balance sheet of this sector.

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[16]For example, a household who wants to buy a house of value h, pays h to a financial firm to purchase the house. The financial firm constructs a home of value h and sells it to the household. The household can also borrow from the financial firm to finance his purchase, using the housing stock as collateral. The loan from the financial firm to the household is the collateralized mortgage loan.

Table 2: Balance Sheet	
Assets	Liabilities
Productive capital, K	Domestic deposits, A^d
Mortgage loans, D	Foreign deposits, A^f
Residential capital, F	

For simplicity, borrowing and lending rates are assumed to be the same, r. Therefore, net return to mortgage loan is r. The no-arbitrage condition implies that in equilibrium, the financial firms must be indifferent between renting productive capital to the firm, offering mortgage loans to homeowners and lending residential housing to renters. Therefore, the rental rate of capital is $r + \delta_k$, and renting price must be equal to the sum of the depreciation of renting and the interest rate, i.e., $r_f = r + \delta_r$.

Following Henderson and Ioannides (1983), we assume that $\delta_r > \delta_o$. This implies that in equilibrium, the price for renting is higher than the user cost of owner-occupied housing, $r + \delta_r > r + \delta_o$. This provides incentives for households to become homeowners. It is important to notice that without this incentive, no household would choose to become a homeowner in this model, since renting strictly dominates owning, ceteris paribus. This is because housing services acquired from the rental market do not involve frictions related to housing, such as transaction costs, downpayment requirements or mortgage payments. Our assumption that rental housing depreciates at a higher rate than owner-occupied housing can be justified with moral-hazard on the side of the tenant.

4.6 Mortgage Structures

This subsection characterizes mortgage payment structures and the household's problems accordingly. To provide a stylized contrast between mortgage market arrangements prevailing in the U.S. economy before and after deregulation, we focus on two polar cases: 1) households purchase home through traditional, fixed-term level payment mortgage contracts but cannot refinance; and 2) households can refinance without any cost.

Our modeling strategy is as follows. In both cases, purchasing a house requires a downpayment, which is proportional to the home's value. This downpayment ratio is denoted by ϕ_1. The difference between the two polar cases lies in the flexibility of the two types of payment schedules. Without refinancing opportunity, households have to accumulate home equity as the payment schedule specifies. In contrast, with refinancing opportunities, households can "rewrite" the mortgage contract to choose the payment stream over the contract period. Moreover they can also borrow from the financial intermediary sector, using housing stock they accumulate as collateral.

4.6.1 Traditional Mortgage: Fixed-Term, Level-Payment Mortgage

Homeowners in this model acquire their home equity with a fixed-payment or fixed-rate mortgage. To model this mortgage contract, we closely follow Chambers et al. (2009a, 2009b). We use similar techniques to formalize the constant payment schedule, which is an important feature of the traditional mortgage regime.

The fixed-term, level payment mortgage loan requires homeowners make *constant* mortgage payments over the length of the mortgage contract. It implies an increasing amortization schedule of the principal and a decreasing schedule for interest payments. Specifically, the initial debt level is d_0, when acquiring a new house, $d_0 = (1 - \phi_1) \cdot h'$, where h' is the size of the purchased house. The constant payment each period is $m = \lambda \cdot d_0$, where λ is a constant number which balances the principal and interest payment schedules. In other words, it is pinned down by the mortgage rate and the length of maturity, or $\lambda = r \cdot \left[1 - (1 + r)^{-T} \right]^{-1}$, where r is mortgage rate and the T is the length of the mortgage contract. Therefore the housing debt evolves as follows:

$$d_t = d_{t-1} \cdot (1 + r) - m.$$

As stressed before, there is no refinancing opportunity in this type of contract, and homeowners constantly reduce the housing debt level until they own all of the home equity, unless they sell the house before the contract ends.

Homeowners could sell their houses or upgrade or downgrade their housing stock holdings. If homeowners sell their houses and become renters, part of the housing value is used for repaying the remaining debt, and homeowners keep the home equity they have accumulated in the past. Similarly, if the homeowners upgrade or downgrade their housing stock holdings, the initial contract is cleared and they must sign a new contract with new debt holding.

To characterize the household's decision in this environment, we introduce another state variable, residual time s, which represents the length of maturity (the number of periods) left before the contract ends. On the one hand, the residual time, s, represents the debt position information of the homeowner. On the other hand, it helps to distinguish different types of households in this economy. For example, if $s = 0$ (residual time is zero) and $h = 0$ (housing stock holding is zero) for households, it implies they are renters in this economy. If $s = 0$ (residual time is zero) and $h > 0$ (housing stock holding is positive), it implies they are homeowners who own the house without any debt. Moreover, If $s > 0$ (residual time is positive) and $h > 0$ (housing stock holding is positive), it implies they are homeowners who own the part of the house that has a positive debt position.

Generally, in this economy, households, either renters or homeowners, choose consumption of nondurable goods and asset holding. If households choose to become home-

owners (or upgrade/downgrade their housing stock), they also decide on the size of the rental unit. If they choose to become renters (or continue to be renters), they have to decide on the size of the rental unit as well. If homeowners stay in their own house, without changing housing size, they consume housing services generated by the housing stock they own and do not need to choose housing size.

Imagine that the homeowners in this economy are hit by negative income shocks. They could be able to use liquid financial assets - deposits - to smooth their consumption. For homeowners with low liquid assets, they can sell or downgrade their housing stock with a positive transaction cost. In other words, they cannot utilize the home equity accumulated in their homes, unless they sell their houses. Because of the transaction cost, there is an "inaction zone" where homeowners with low liquid assets do not adjust their housing stock, even after being hit by a negative income shock. Even in that case, they must pay the mortgage loan as scheduled, namely the committed expenditures. In this case, they have to adjust their consumption to a lower level.

Household's problem   Households choose (z', c, a', h', f) to maximize,

$$V_j(e, a, h, s) = \max_{c, h^s, a', s', z'} \left\{ u(c, h^s) + \psi_{j+1} \cdot \beta \cdot E_{e, e'} V_{j+1}(e', a', h', s') \right\},$$

where $c > 0, a' \geqslant 0, h' \geqslant \underline{h}, f \geqslant 0, s' \geqslant 0, z' = 1$ or 0. Note that we assume the minimum housing size in this economy is $\underline{h}$. In other words, homeowners can choose housing size between $[\underline{h}, \infty]$.

The law of motion for s, especially needs elaboration. For households who were renters yesterday and become homeowners today, $s = 0$ and $s' = T$. For households who were renters yesterday and are still renters today, $s = 0$ and $s' = 0$. For households who were homeowners yesterday and become renters today, $s \geqslant 0$ and $s' = 0$. For households who were homeowners yesterday and upgrade or downgrade their housing today, $s \geqslant 0$ and $s' = T$.

The choice is subject to the following budget constraint,

$$c + a' + (1 - z') \cdot r_f \cdot f + tr(h', h) + \lambda \cdot (1 - \phi_1) \cdot h \cdot I(s > 0) \cdot I(h = h')$$
$$+ \phi_1 \cdot h' \cdot (z \cdot (1 - I(h = h')) + (1 - z)) + \delta_o \cdot h \cdot z \cdot I(h = h') + \delta_o \cdot h' \cdot z' \cdot (1 - I(h = h'))$$
$$= w \cdot e \cdot v_j \cdot (1 - I(j \geqslant j^*)) + p \cdot I(j \geqslant j^*) + (1 + r) \cdot a + z \cdot (h - d_{T-s}) \cdot (1 - I(h = h')).$$

where indicator function $I(x)$ takes value one if the relation x is true, and zero otherwise. Left-hand side of the equation gives the spending decisions households make, while the right hand side gives household's resources. All the households have to decide on consumption c, and asset holding, a'. If households choose to become renters for this period, $z' = 0$, they have to choose the size of the rental unit, f. And if homeowners

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choose to upgrade or downgrade their housing stock or become renters, they decide on housing size, h' or renting size, f. A transaction cost, $tr(h', h)$, has to be paid by households, who make housing transactions. If they are homeowners at the beginning of this period and decide not to move, $I(h = h') = 1$, they make mortgage payments, $\lambda \cdot (1 - \phi_1) \cdot h$, conditional on their mortgage contract has not been finished, $I(s > 0) = 1$. Otherwise, homeowners pay zero in mortgage payments. Homeowners at the beginning of this period who want to upgrade and downgrade their housing, pay a new downpayment for the new house they buy during this period. The same is true for renters at the beginning of this period who choose to become homeowners. Homeowners who do not want to move, must maintain their house by paying $\delta_o \cdot h$. Movers and new home owners, must maintain the newly purchased house, $\delta_o \cdot h'$.

The right-hand side of the budget constraint describes household resources. The working cohorts of households receive labor income of $w \cdot e \cdot v_j$, and the retired cohorts receive pension benefits of p. All of them receive returns on the asset holding $(1 + r) \cdot a$, unless the asset position is zero. For homeowners who want to move, they need to sell their house and clear up the housing debt, if any. The rest become resources for them to use, $h - d_{T-s}$. The household problem can be decomposed into several distinct situations.

Renters who continue to be renters Suppose that the household is a renter at the beginning of the period and continues to be a renter during this period again. The housing stock holding is simply zero both at the beginning and at the end of the period, that is $h = 0$ and $h' = 0$. The renter only needs to decide on renting size f and there is no mortgage-related expenditures. Denote the labor income or pension income as $y_{e,j} = w \cdot e \cdot v_j \cdot (1 - I(j \geqslant j^*)) + p \cdot I(j \geqslant j^*)$. The recursive form of the decision problem is stated as follows:

$$V_j(e, a, 0, 0) = \max_{c, f, a'} \{u(c, f) + \psi_{j+1} \cdot \beta \cdot E_{e,e'} V_{j+1}(e', a', 0, 0)\}$$

$$s.t.$$

$$c + a' + r_f \cdot f = y_{e,j} + (1 + r) \cdot a.$$

Homeowners who are becoming renters Suppose that the household is a homeowner at the beginning of the period and chooses to be a renter during this period. The housing stock is positive both at the beginning of the period and zero at the end of the period, that is $h > 0$ and $h' = 0$. The household only needs to decide on renting size f. The difference from the last case is that the homeowner needs to sell the house he owns and repays the debt he owes to the bank, $h - d_{T-s}$. At the meantime a transaction cost

is incurred, $tr(0, h)$. The recursive form of the decision problem is stated as follows:

$$V_j(e, a, h, s) = \max_{c, f, a'} \left\{ u(c, f) + \psi_{j+1} \cdot \beta \cdot E_{e, e'} V_{j+1}(e', a', 0, 0) \right\}.$$

s.t.

$$c + a' + r_f \cdot f + tr(0, h) = y_{e,j} + (1 + r) \cdot a + h - d_{T-s}.$$

Homeowners who choose to stay   Suppose that the household is a homeowner at the beginning of the period and chooses to stay in his own house during this period. The housing stock is positive both at the beginning of the period and remains the same at the end of the period, that is $h = h'$. The household does not need to decide on the housing size. The home owner needs to maintain the house and pay $\delta_o \cdot h$. If the standard contract is not finished yet, or $s > 0$, he also has to make the mortgage payment, $\lambda \cdot (1 - \phi_1) \cdot h$. If he owes the entire home equity or $s = 0$, he need not pay the mortgage. The recursive form of the decision problem is stated as follows:

$$V_j(e, a, h, s) = \max_{c, a'} \left\{ u(c, h) + \psi_{j+1} \cdot \beta \cdot E_{e, e'} V_{j+1}(e', a', h, \max(s - 1, 0)) \right\}$$

s.t.

$$c + a' + \lambda \cdot (1 - \phi_1) \cdot h \cdot I(s > 0) + \delta_o \cdot h = y_{e,j} + (1 + r) \cdot a.$$

Homeowners who upgrade or downgrade   Suppose that the household is a homeowner at the beginning of the period and chooses to upgrade or downgrade his housing stock during this period. The housing stock is positive both at the beginning and at the end of the period, although they are not the same, that is $h \neq h'$. The household needs to decide on the housing size, h'. The homeowner first needs to sell the house he owns and repays the debt he owes to the bank. The remaining equity is $h - d_{T-s}$. He has to start a new mortgage contract to buy a new house. Therefore, the state variable which keeps track of the number of periods left before the mortgage contract finishes, is reset to T. He has to pay a downpayment for the new house, $\phi_1 \cdot h'$, the transaction cost incurred, $tr(h', h)$, and the maintenance fee, $\delta_o \cdot h'$. The recursive form of the decision problem is stated as follows:

$$V_j(e, a, h, s) = \max_{c, h', a'} \left\{ u(c, h') + \psi_{j+1} \cdot \beta \cdot E_{e, e'} V_{j+1}(e', a', h', T) \right\}$$

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$$s.t.$$

$$c + a' + tr\left(h', h\right) + \phi_1 \cdot h' + \delta_o \cdot h' = y_{e,j} + \left(1 + r\right) \cdot a + h - d_{T-s}.$$

Renters who are becoming homeowners Suppose that the household is a renter at the beginning of the period and chooses to be a homeowner during this period. The housing stock at the beginning of this period is zero and positive at the end of this period, that is $h = 0$ and $h' > 0$,respectively. He needs to decide on the housing size. He has to make a downpayment for the new house, $\phi_1 \cdot h'$, the transaction cost incurred, $tr\left(h', 0\right)$ and the maintenance fee, $\delta_o \cdot h'$. The recursive form of the decision problem is stated as follows:

$$V_j\left(e, a, 0, 0\right) = \max_{c, h', a'} \left\{u\left(c, h'\right) + \psi_{j+1} \cdot \beta \cdot E_{e,e'} V_{j+1}\left(e', a', h', T\right)\right\}.$$

$$s.t.$$

$$c + a' + tr\left(h', 0\right) + \phi_1 \cdot h' + \delta_o \cdot h' = y_{e,j} + \left(1 + r\right) \cdot a.$$

4.6.2 Flexible Refinancing

This subsection details the other polar case, that is, homeowners have options to refinance. Refinancing in this model is defined broadly. Except for changing downpayment ratio (or the initial home equity holding), all the refinancing activities, including taking additional mortgage loans and negotiating payment schedules are considered. This definition implies homeowners would be able to alter the monthly payments owed on the loan, or by altering the loan's term of maturity.. One could think of a case in which homeowners can sign a new contract at the end of every period (periodically refinancing). Moreover, they can also borrow from the financial intermediary by using their home equity as collateral. In essence, homeowners can access collateral lending, subject to the constraint that mortgage debt does not to exceed a certain limit. Downpayment is considered as the minimum home equity, which must be owned by the homeowner. We adopt the assumption that total borrowing cannot exceed a fraction, $1 - \phi_1$, of home value. This assumption has been widely used in the housing literature (for example, Diaz and Luengo-Prado(2008)). Therefore, a homeowner's debt evolves as follows:

$$d' \leqslant \left(1 - \phi_1\right) \cdot h'.$$

Imagine that the homeowners in this economy are hit by negative income shocks. They

could use liquid financial assets - deposit - to smooth their consumption. For homeowners with low liquid assets, they could also make use of the home equity they have accumulated, without selling their house. It is the refinancing channel of consumption smoothing.

Household's problem   Households choose (z', c, a', h', f) to maximize,

$$V_j (e, a, h, d) = \max_{c, h^s, a', z'} \{ u (c, h^s) + \psi_{j+1} \cdot \beta \cdot E_{e,e'} V_{j+1} (e', a', h', d') \}$$

where $c > 0$, $a' \geqslant 0$, $h' \geqslant \underline{h}$, $f \geqslant 0$, $z' = 1$ or 0. Technically, comparing with the previous case, we can see that the state variable s is not being useful for homeowners to make their decision, since households could refinance any time when they need to. The budget constraint for households is the following:

$$
\begin{aligned}
& c + a' + (r + 1) \cdot d \cdot I (h = h') + (1 - z') \cdot r_f \cdot f + tr (h', h) \\
& + h' \cdot (z \cdot (1 - I (h = h')) + (1 - z)) + \delta_o \cdot [h \cdot z \cdot I (h = h') + \cdot h' \cdot z' \cdot (1 - I (h = h'))] \\
& = w \cdot e \cdot v_j \cdot (1 - I (j > j^*)) + p \cdot I (j > j^*) + r \cdot a + (h \cdot z - d) \cdot (1 - I (h = h')) + d'.
\end{aligned}
$$

The left-hand side of equation provides spending decisions of households. All the households have to decide on consumption c, and asset holding, a'. If households choose to become renters for this period, $z' = 0$, they have to choose the size of the rental unit, f. And if homeowners choose to upgrade or downgrade their housing stock or become renters, they decide on housing size, h', or renting size, f. Households, that make housing transactions, must pay a transaction cost, $tr (h', h)$. If they are homeowners at the beginning of this period and decide not to move, $I (h = h') = 1$, they service mortgage debt they hold by paying $r \cdot d$. Homeowners at the beginning of this period who want to upgrade or downgrade their housing pay h' for the new house. This is the same for renters at the beginning of this period who choose to become homeowners. Homeowners who do not want to move must maintain their house by paying $\delta_o \cdot h$. Movers and new home owners must maintain the newly purchased house, $\delta_o \cdot h'$.

The right-hand side of the budget constraint provides the household's resources. The working cohorts of households receive labor income $w \cdot e \cdot v_j$, and the retired cohorts receive pension benefit of p. All of them receive returns on the asset holding $(1 + r) \cdot a$, unless the asset position is zero. Homeowners who want to move must sell their house and clear up the remaining debt. The rest becomes resources for them to use, $h - d$. Homeowners are also free to choose a new debt level, d'. Several distinct situations can be also laid out as follows.

Renters who continue to be renters   Suppose that the household is a renter at the beginning of the period and continues to be a renter during this period as well. The housing stock is simply zero both at the beginning and at the end of the period, that is $h = 0$ and $h' = 0$. The renter only needs to decide on renting size f. Technically, the form of mortgage contract does not affect this type of households. The recursive form of the decision problem is stated as follows:

$$V_j\left(e, a, 0, 0\right) = \max_{c,f,a'}\left\{u\left(c, f\right) + \psi_{j+1} \cdot \beta \cdot E_{e,e'}V_{j+1}\left(e', a', 0, 0\right)\right\}$$

$$s.t.$$

$$c + a' + r_f \cdot f = y_{e,j} + \left(1 + r\right) \cdot a.$$

Homeowners who are becoming renters   Suppose that the household is a home-owner at the beginning of the period and chooses to be a renter during this period. The housing stock is positive both at the beginning of the period and zero at the end of the period, that is $h > 0$ and $h' = 0$. The household only needs to decide on renting size f. The difference from the last case is that the homeowner needs to sell the house he owns and repays the debt he owes to the bank. The remaining equity is $h - d$. The new debt level is zero, since he chooses to be a renter this period. At the meanwhile, a transaction cost is incurred, $tr\left(0, h\right)$. It It appears that the form of mortgage contract does not take effect on households in this situation. However, implicitly, homeowners might be less likely to choose to be renters in the current market arrangement than homeowners who have no refinancing opportunities in the previous case, given reasonable negative income shocks. They could choose to stay and refinance, unless they are close to the borrowing limit. The recursive form of the decision problem is stated as follows:

$$V_j\left(e, a, h, d\right) = \max_{c,f,a'}\left\{u\left(c, f\right) + \psi_{j+1} \cdot \beta \cdot E_{e,e'}V_{j+1}\left(e', a', 0, 0\right)\right\}$$

$$s.t.$$

$$c + a' + r_f \cdot f + tr\left(0, h\right) = y_{e,j} + \left(1 + r\right) \cdot a + h - d.$$

Homeowners who choose to stay   Suppose that the household is a homeowner at the beginning of the period and chooses to stay in his own house during this period. The housing stock is positive both at the beginning of the period and remains the same at the end of the period, that is $h = h'$. The household does not need to decide on the housing

size. He needs to maintain the house and pay, $\delta_o \cdot h$. Unlike the traditional mortgage case, where he makes a constant mortgage payment and cannot change the debt holding, there is no committed payment to fulfill and he can adjust the debt level. However, he has to pay the interest on the existing debt. The recursive form of the decision problem is stated as follows:

$$V_j\left(e, a, h, d\right) = \max_{c, a'}\left\{u\left(c, h\right) + \psi_{j+1} \cdot \beta \cdot E_{e, e'} V_{j+1}\left(e', a', h, d'\right)\right\}$$

$$s.t.$$

$$c + a' + \left(1 + r\right) \cdot d + \delta_o \cdot h = y_{e, j} + r \cdot a + d',$$

$$d' \leqslant \left(1 - \phi_1\right) \cdot h.$$

Homeowners who upgrade or downgrade Suppose that the household is a homeowner at the beginning of the period and chooses to upgrade or downgrade his housing stock during this period. The housing stock is positive both at the beginning and at the end of the period, although they are not the same, that is $h \neq h'$. The household needs to decide on the housing size, h'. The homeowner first needs to sell the house he owns and repay the debt he owes to the bank. The remaining equity is $h - d$. He has to pay for the new house. He could choose to borrow against home equity, and he decides on the new debt level, d'. A transaction cost incurred and must be paid, $tr\left(h', h\right)$. The recursive form of the decision problem is stated as follows:

$$V_j\left(e, a, h, d\right) = \max_{c, h', a'}\left\{u\left(c, h'\right) + \psi_{j+1} \cdot \beta \cdot E_{e, e'} V_{j+1}\left(e', a', h', d'\right)\right\}$$

$$s.t.$$

$$c + a' + tr\left(h', h\right) + h' + \delta_o \cdot h' = y_{e, j} + \left(1 + r\right) \cdot a + h - d + d',$$

$$d' \leqslant \left(1 - \phi_1\right) \cdot h'.$$

Renters who are becoming homeowners Suppose that the household is a renter at the beginning of the period and chooses to be a homeowner during this period. The housing stock at the beginning of this period is zero and positive at the end of this period, that is $h = 0$ and $h' > 0$. The household needs to decide on the housing size. He has to

pay for the new house. He could choose to borrow against home equity, and he decides on the new debt level, d'. A transaction cost incurred has to be paid, $tr(h', 0)$. The recursive form of the decision problem is stated as follows:

$$V_j(e, a, 0, 0) = \max_{c, h', a'} \{u(c, h') + \psi_{j+1} \cdot \beta \cdot E_{e, e'} V_{j+1}(e', a', h', d')\}$$

$$s.t.$$

$$c + a' + tr(h', 0) + h' + \delta_o \cdot h' = y_{e,j} + (1 + r) \cdot a + d',$$

$$d' \leqslant (1 - \phi_1) \cdot h'.$$

4.7   Stationary Equilibrium

We focus on an open-economy stationary equilibrium in which the interest rate, r, is determined exogenously by the international market.[17] The representative firm chooses the optimal factor inputs in production then determines the wage rate per efficiency unit, w. An exogenous interest rate is particular important and attractive for this model: we want to single out the net effect of contract regimes, and it is extremely important to fix the interest rate in both economies. The interest rate affects mortgage debt payment, asset return, as well as household's inter-temporal choice. In a close economy equilibrium, however, the interest rate is endogenously higher in the refinancing regime, since households accumulate less precautionary savings, which boosts the interest rate. Moreover, one important feature of the U.S. economy is that domestic investment is financed by resources from abroad. Therefore it is more suitable to adopt the open-economy equilibrium.

The state of an individual is fully characterized by a vector of state variables, including idiosyncratic labor productivity, liquid asset holdings, housing stock, mortgage status or debt information and household age. For notational efficiency, we denote the state vector $x = \{e, a, h, s, j\}$ and the state space $X = \{E \times [0, \overline{a}] \times [\underline{h}, \overline{h}] \times S \times J\}$, where $\overline{a}$ and $\overline{h}$ are the upper bounds for financial assets and housing stock in this economy.[18] And the distribution of the households over the state space X is Ω.

1. The representative firm in the goods sector takes interest rate, r, as given, and

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[17]A similar approach has been used by Fernandez-Villaverde and Krueger (2010), Kaplan (2007) and Heathcote, Storesletten, and Violante (2008).

[18]The variables $\overline{a}$ and $\overline{h}$ are so large that households do not accumulate financial assets and housing stock more than $\overline{a}$ and $\overline{h}$, given the exogenous income process.

chooses an optimal factor inputs ratio of $\frac{K}{L}$:

$$r = \alpha \cdot \left(\frac{K}{L}\right)^{\alpha-1} - \delta_k.$$

And the wage rate, w, is implied:

$$w = (1 - \alpha) \cdot \left(\frac{K}{L}\right)^{\alpha}.$$

2. The domestic labor markets clear: given wage rate w, a firm's labor demand equals the aggregation of individual labor supply, $L = \int_X e \cdot v \cdot \bar{l} \ d\Omega$.

3. Given factor prices, interest rate r and wage w, the value function and decision rules are solved for the household optimization problem, namely, $V(x)$, $a'(x)$, $h'(x)$, $f(x)$, $s'(x)$ and $c(x)$.

4. The government runs balanced budget, $T = P$, where $T = \tau \cdot w \cdot L$ is the total labor income tax from working cohorts, and $P = p \cdot \sum_{j=j^*}^{J} \mu_j$ is the total pension payment to retired cohorts. The implied tax rate is $\tau = \frac{P}{w \cdot L}$.

5. Financial market clears, $A^d = \int_X a'(x) \ d\Omega$.

6. Renting market clears, $F = \int_X f(x) \ d\Omega$.

7. Housing market clears, $H = \int_X h'(x) \ d\Omega$.

8. Financial intermediary firm maximizes profit and earns zero profit.

9. Domestic goods market clears, namely,

$$C + \delta_o \cdot H + \delta_k \cdot K + \delta_r \cdot F + \Upsilon + NX = K^\alpha L^{1-\alpha}.$$

where C, H, K, F, Υ and NX are the aggregate nonhousing consumption, aggregate housing stock, aggregate physical capital, residential housing, aggregate transaction cost and current account in this economy.

10. World asset market clears, which requires the change in net foreign asset position equals the current account, namely,

$$r \cdot (D + K + F - A^d) = NX.$$

where D is domestic aggregate mortgage debt.

11. The distribution, Ω, over the whole state space, i.e., age, financial assets, housing stock, earning shocks, and mortgage status (or debt) is invariant.

5 Quantitative Analysis

In this section, we evaluate how financial liberalization affects aggregate trends, such as the saving rate/consumption share, debt holding and the homeownership rate. We use the model with traditional mortgage loans as a benchmark, which approximates the pre-deregulation economy in early 1980. To analyze the impact of financial liberalization, we conduct the following experiment:

Experiment 1: Compute the model with traditional mortgage loans with a high downpayment ratio.

Experiment 2: Compute the model with refinancing opportunities with a high downpayment ratio.

Experiment 3: Compute the model with refinancing opportunities with a low downpayment ratio.

Experiment 4: Compute the model with traditional mortgage loans with a low downpayment ratio.

The differences between Experiments 1 and 3 gives the full impact of financial deregulation. To analyze the impact of refinancing opportunities, we compare results from Experiments 1 and 2. To analyze the role that low downpayment ratio plays during financial liberalization, we compare results between Experiments 2 and 3. We also conduct a counter factual Experiment 4, where a lower downpayment ratio is allowed but refinancing opportunities are not available. The comparison between Experiments 1 and 4, allows us to identify how the lowering downpayment ratio alone could affect the aggregate trends.

It is important to note that, results from our experiments can separate the effects of lowering downpayment requirements from the effects of refinancing. In reality, both increasing availability of refinancing and decreasing downpayment requirements happened at the same time during financial liberalization. Previous studies usually regard lower downpayment requirements as an increase in access to housing equity, and use this change alone to approximate the impact of financial liberalization. However, as we highlight in previous text, given the standard payment schedule (or the first mortgage regime in this paper), low downpayment requirements do not necessarily imply more access to home equity at all. As acknowledged by Díaz and Luengo-Prado (2009), previous literature

cannot "disentangle one from the other"(page 21). It is important to separate the role of refinancing options from the role of lowering downpayment requirements, especially when it comes to evaluating the effects of different policies in the housing market.

5.1 Calibration Strategy

We choose to calibrate the economy with traditional mortgage loans to match important features of the pre-deregulation U.S. economy in the early 1980s. Calibration of the benchmark economy is the in the following order: demographics and timing, preferences, the earnings process, the technology, and housing and renting markets. The parameters are summarized in Table 3.

Table 3: Baseline Parameters: Pre-Deregulation

Parameter	Economic interpretation	Value
	Demographics	
J	Maximum age	12
ψ	Mortality risk	United Nations (2002)
	Preferences	
σ	CRRA risk aversion	2.00
β	Annual discount rate	0.9575
γ	Nonhousing consumption weight	0.85
	Technology	
η	Capital share	0.30
δ_k	Capital depreciation rate	0.08
	Earning process	
ρ	Persistence	0.989
σ_e	Standard deviation	0.0158
v_j	Efficiency index	Hansen(2003)
	Housing market	
ϕ_1	Downpayment ratio	0.20
τ_b	Percentage cost of buying	0.02
τ_s	Percentage cost of selling	0.07
δ_r	Renting depreciation rate	0.14
δ_o	Owning depreciation rate	0.043
$\underline{h}$	Minimum housing size	0.40

Source:Standard and calibrated parameters

Demographics and Timing   To ease the computational burdens, one model period is five years.[19] Households are born at age 20, and die at the maximum age of 80. The retirement age is 60. Survival probabilities are taken from United Nations (2002), which provides the survival probability for the year of 2000.

Preferences   We use the following standard Constant Relative Risk Aversion (CRRA) utility function. The Cobb-Douglas aggregator between housing consumption and non-durable consumption is used.

$$u(c, h^s) = (c^\gamma \cdot h^{s1-\gamma})^{1-\sigma}/(1-\sigma)$$

Housing services provided by owner-occupied housing are assumed to be same as the housing stock owned by the owners. The coefficient of risk aversion, σ, is set to 2, which is commonly used in the literature. The weight households put on nonhousing consumption, γ, is calibrated to match the ratio of housing services to nonhousing consumption, which was 0.23 in the early 1980s.[20] The annual discount factor, $\beta = 0.9575$, is calibrated to match the nonhousing wealth to income ratio, 2.5, (See Kaplan and Violante 2010).

Earnings Process   There are a number of estimations of risky earning process in the literature. We choose to follow Díaz and Luengo-Prado (2009).[21] They estimate that the persistence and variance are $\rho = 0.9895$ and $\sigma_e = 0.0158$, respectively.[22] We approximate the AR(1) process by a 5-point Markov chain, using the procedures described in Tauchen (1986).

The mean efficiency index over a life cycle is taken from Hansen (1993) so that the model could replicate the cross-section age distribution of earnings of the U.S. economy. Notice that the age-specific productivity profile is hump-shaped and peaks at age 50. The household's inelastic labor supply is chosen to be $\bar{l} = 0.3$. The replacement ratio is the ratio of retirement pension income to last year's working cohorts' labor income. It is taken from Chambers et al. (2009a) and set at 0.3. The labor income tax rate is solved endogenously, consistent with the assumption of a balanced government budget.

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[19]We translate all the parameters at annual frequency into the ones for a model period of five years. All the parameters reported are annual data.

[20]Housing services are defined as the value of housing consumption, that is, the sum of renting and owning housing stock evaluated by the renting price.

[21]Alternatively, we can choose to follow Storesletten, Telmer, and Yaron (2004), where earning is defined as wage earnings plus transfer. They also allow for transitory shocks and fixed effects. Therefore, their estimations of persistence and variance are $\rho = 0.9989$ and $\sigma_e = 0.0166$. Díaz and Luengo-Prado (2009)'s estimation is closer to our purpose. However, it is important to know that the difference in various estimations is small and they give very similar results.

[22]They find that this process can deliver a reasonable Gini index for earnings of regular households (as in the SCF-98), and a coefficient of variation (CV), which is very similar to the one in the SCF-98 for households outside the top 1 percent of the earnings distribution.

Technology Similar to Fernandez-Villaverde and Krueger (2010), we fix the interest rate at 3% in both of the economies by choosing a capital level K. The wage rate for efficient labor unit is implied. The depreciation rate of capital, δ_k, is set at 0.08. The share of physical capital in output is $\alpha = 0.30$, which is standard in the literature.

Housing and Renting Markets We set the selling cost equal at 7 percent and buying cost at 2 percent of the housing values. They are consistent with Martin and Gruber (2004), who document buying and selling cost with CEX data. The downpayment ratio is set at 0.20 for the early 1980s case, which is close to the average downpayment reported by the Federal Housing Finance Board and similar to Campbell and Hercowitz (2009)'s estimation as well, see Table 1.

We calibrate renting depreciation rate, δ_r, the owning depreciation rate, δ_o, and the minimum housing size, $\underline{h}$, to jointly match the economy-wide homeownership rate, which was 64% in early 1980s, housing to physical capital stock ratio, 0.60, and the housing investment-stock ratio, 0.043.

Post-Deregulation U.S. Economy The post-deregulation U.S. economy is characterized by the model with refinancing opportunities and lower downpayment ratios. We use exactly the same set of parameters for this economy, except that households in this economy can access refinancing opportunities and the downpayment requirement is lower. Table 1 shows that the average equity-value ratio for newly purchased homes in 1983 was 22.6%, and this ratio has decreased to 16.4% by 2001, Campbell and Hercowitz (2009). We thus experiment with a downpayment ratio of 15% for the post-deregulated economy.

5.2   Quantitative Results

5.2.1   Homeownership Rate and Debt Holding

Table 4: Trends

Downpayment	Regime	Ownership	Debt Ratio	Cons Share
High	NR	64%	26%	92.6%
High	R	70%	47%	93.8%
Low	R	75%	56%	94.9%

Source: Numerical Experiments.

The homeownership rate is the percentage of homeowners in this economy. The homeownership rate is substantially higher in the case where refinancing is allowed. It

goes up from 64% to 70%, given that we keep the downpayment ratio as high as 20%. Lowering the downpayment ratio further helps to increase the homeownership rate by 5 percentage points. Compared to data where the homeownership rate increases from 64% to 69%, the model over predicts the change.[23]

Without refinancing opportunities, homeowners who experience negative income shocks cannot make use of home equity they accumulate, unless they choose to sell or downgrade their housing stocks. Refinancing options allow homeowners to access their home equity without selling or downgrading their home. Therefore, there are two channels by which the homeownership rate can increase. Firstly, refinancing opportunities create fewer renters, given the same magnitude of negative income shocks. Secondly, anticipating that home equity can be easily accessed, households have more incentive to build up housing stock and start accumulating housing stock earlier. Compared with the previous literature which argues that demographic changes are important for the increase in homeownership rate (see Chambers et al. 2009a), we stress financial liberalization also plays an important role.

It should be noted that our model shows that allowing homeowners to access equity can induce more households to purchase homes. This effect plays a major role during financial liberalization. Lowering downpayment does help increase the homeownership rate but turns out to be relatively less important.

We observe that the debt to labor income ratio increases in the refinancing model, compared with the traditional mortgage model. The net mortgage debt to labor income ratio is only 26%, in the case of the traditional mortgage. And it increases to 47%, when we allow homeowners access to refinancing opportunities. Decreases in downpayment ratios drives this ratio further to 56%. In total, the two mechanisms combined can deliver an increase of 30 percentage points, roughly in line with the increase of 37 percentage points in the data. While we under-predict the absolute level of net mortgage debt, we successfully deliver the substantial change in debt levels.[24] We also observe that the new borrowers increased by 8 percentage points, from 18% in the pre-deregulation economy, up to 26% in the post-deregulation economy. It is also consistent with the increase of 7 percentage points in the data.

These results are intuitive. Firstly, they go hand in hand with the fact that the homeownership rate is higher. More households are willing to become homeowners and

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[23]Our model over-predicts changes in homeownership rate. It is largely due to the fact that our experiments assume an uniformed downpayment ratio and equal access to refinancing opportunities. In reality, some households may not be eligible for refinancing, and effective downpayment ratios also vary across groups with different eligibility.

[24]As it is well-known in the literature, the parameters used in our calibration of the earnings process are not capable of generating enough wealth inequality, compared to the data (see, for example, Castaneda et al. 2003). Clearly, this also implies too little debt in the aggregate, since the wealth-poor are too rich with respect to the data. Our calibration strategy is standard in the literature, which facilitates a comparison to the previous literature. We leave it to future work to re-calibrate the earnings process to match wealth inequality and debt holdings exactly.

purchase homes. They borrow from the financial intermediary, using housing stock as a collateral. This results in a higher level of debt, given a certain labor income. Secondly, refinancing opportunities allow homeowners to raise more debt, when adverse income shocks occur. In the traditional mortgage environment, homeowners with very low liquid assets, they have to sell or downgrade their housing stock to insure themselves against adverse income shocks. In the case of refinancing, the homeowners can borrow against their home equity to smooth out consumption. Thirdly, lowered downpayment requirements allow homeowners to make use of an even larger share of the home equity, and the first two mechanisms are amplified. Comparing the two channels of financial liberalization, we also find those opportunities which allows homeowners to access home equity has a stronger effect than lowered downpayment requirement does.

Scoccianti (2009) also finds that a lower downpayment ratio does not generate substantial increase in net debt. He concludes that earning shocks must be more permanent over time so that more households are borrowing constrained and higher debt levels arise. However, Blundell, Pistaferri, and Preston (2008) find that the transitory component of earning risk in the labor income process has increased, and the permanent component has actually decreased. It seems difficult to reconcile Scoccianti (2009)'s conclusion to what the data suggest. We use a very standard, stochastic labor income processes for both the pre and post-deregulation economy. The experiments show that the net mortgage debt can increase substantially even without any increase in the persistence of income shocks. We stress that refinancing opportunity plays a key role in the rising indebtedness during financial liberalization.

5.2.2 The Consumption Boom and The Decline of Saving Rate

As subsection 2.5 showed, it is useful to use the consumption share of personal income to measure the trend of household saving rate.[25] We observe that the aggregate consumption share (the ratio of aggregate consumption to disposable income) does increase by 2.3 percentage points, from 92.6% to 94.9%. We find that allowing for refinancing options accounts for roughly half of the increase generated by the model, while the lower downpayment ratios accounts for the other half. It demonstrates that financial liberalization is responsible for roughly one-third of the consumption boom in the U.S. economy.

We find that precautionary savings is substantially lower in the post-deregulation economy. With refinancing, housing capital becomes a close substitute for the liquid

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[25]The aggregate consumption is defined by the sum of the nonhousing consumption and imputed housing consumption. Housing consumption is composed of renting service and housing service generated by owner-occupied housing. Following the "user cost "approach, it is evaluated by "owning price", namely the depreciation rate of owner-occupied housing plus interest rate. According to the NIPA definitions, however, the imputed value of owner-occupied housing is computed by using the "rental price". In our case, this is higher than the user-cost approach. This implies that the increase in consumption would be even larger if we followed the NIPA definition. Personal income is defined by the sum of domestic households' labor income and return to financial assets.

assets (or financial saving), although still inferior, in terms of insurance against earning shocks. Because the housing stock becomes relatively more "liquid" and consuming owner-occupied housing is cheaper than renting, households choose to hold relatively more housing stock than households in the pre-deregulation economy. Meanwhile, they save less liquid financial assets out of precautionary motives.

Less precautionary savings release more resources for consumption purposes. Since owner-occupied housing also provides housing consumption services, households consume more housing services as well.

Feldstein (2008) points out that financial innovations and refinancing in the housing market help homeowners access home equity; therefore, they borrow more and save less. Our model shows that financial liberalization helps households build up more housing stock and save less in financial assets. In other words, they "save" more in housing assets and they consume more housing services.

Mendoza et al. (2007) argues that financial development in the U.S. economy helps to reduce precautionary saving. Therefore, part of the investment is financed by foreign capital inflow. In our model, we also observe both of them. We lend support to Mendoza et al. (2007) by showing that financial liberalization in the housing market is an important aspect of the financial development.

5.2.3 Downpayment Requirements: High vs. Low

In this subsection, we identify the impact that lowering downpayment requirements alone could have, on the aggregate trends. We thus conduct a counter-factual experiment, where the downpayment requirement is lower but refinancing is still not allowed. Interestingly, it turns out that the homeownership rate and debt holding do not increase. Similarly, consumption share does not increase either. These results are less surprising, because homeowners in this model are still required to build up home equity over time, despite the lowered downpayment requirements. They still cannot make use of the home equity they have accumulated in the past.

However, as we documented before, we observe an increase in the homeownership rate, debt holding and consumption share, when we decrease downpayment requirements in the model with refinancing. These results are also intuitive. Since homeowners in this model could make use of an even larger share of home equity, the effects of removing forced-home-equity-saving (or accessing to home equity) on the aggregate trends are amplified.

In summary, these results show that: 1) financial instruments, which allow homeowners to have better access to home equity are critical part of financially liberalization. And without refinancing opportunities, lowering downpayment ratios only affects the trends marginally at the best; 2) However, the lowered downpayment ratio amplifies the effect

induced by the availability of refinancing opportunities.

The lessons learned from these experiments have strong policy implications: policies which encourage low downpayment ratios alone are not responsible for the substantial change in the aggregate trends, while policies that promote refinancing opportunity are critical.

5.2.4 Risk-Sharing

Our analytical model shows that allowing for refinancing options lowers precautionary saving and leads to more risk-sharing. Our results from the previous sections showed that the drop in precautionary saving is indeed substantial. We now analyze the impact of financial deregulation on risk-sharing. We measure risk-sharing as the variance of the individual (nonhousing) consumption share $C_i/\bar{C}$, where $\bar{C}$ is the average consumption. In an environment with perfect risk-sharing, their consumption across time and income states, the variance is zero or $C_i = \bar{C}$. We compute this measure for the whole population in both economies. Since the refinancing channel directly helps the working population who face labor income risks to smooth out consumption, we also compute the risk-sharing for the working population. The main results are summarized in the Table 5.

Table 5: Risk-Sharing

Downpayment	Regime	Whole Pop	Working Pop
High	NR	0.617	0.608
High	R	0.610	0.594
Low	R	0.608	0.593

Source: Numerical Experiments.

We find that for the whole population, the variance of individual consumption relative to the average consumption decreases from 0.617 in the traditional mortgage economy to 0.610 in the refinancing economy. If we lower the downpayment ratio, it drops further to 0.608. The total difference in the risk-sharing measures between the pre- and post-deregulated economies is 0.009. And the difference between working populations in these two types of economies is relatively larger, 0.015. In the traditional mortgage economy, the variance is 0.608. And in the refinancing case, it drops to 0.594, and the lower downpayment ratio reduces the variance further to 0.593. This larger difference is expected, since refinancing helps the working population to insure against labor income risks, while the retired population in both types of economies do not face income risks.

It should be noted that the variance we compute is a measure of the overall risk-sharing effect of different insurance channels. Since, in the traditional mortgage case, the

insurance channels are limited to self-insurance (for the whole population) and downgrading housing size (for the homeowners). In the refinancing case, the additional risk-sharing channel (using home equity) would allow households to rely less on the self-insurance. One evidence is that the aggregate precautionary savings in the refinancing case is substantially lower than the non-refinancing case. In other words, they substitute the home-equity risk-sharing channel for the standard precautionary-saving, self-insurance channel. Our results show that refinancing opportunities make households better off in terms of risk-sharing, despite the fact that they make less use of the self-insure mechanism. In other words, the difference in the risk-sharing measures of the two regimes under-predicts the effect of risk-sharing provided by the refinancing channel.

Our results contribute to the literature that measures risk-sharing opportunities in incomplete market models. In an important contribution, Krueger and Perri (2006) argue that allowing for more debt (through relaxing borrowing constraints) in an Aiyagari-type incomplete markets model results in less risk-sharing because debt is state-contingent. We show that this result does not hold in a life-cycle economy when the increase in debt is generated by relaxing payment requirements of mortgage loans.

6   Conclusion

In this paper, we evaluated the impact of deregulation of housing finance with a quantitative life-cycle model. Overall, our model can deliver a substantial increase in net mortgage debt, one third of the increase of total consumption share. The increase in homeownership rate is also consistent with the aggregate trend. Moreover, we can separate the effect of the two aspects of financial liberalization. We also show refinancing opportunities play a key role in financial liberalization.

There are several important aspects of the housing market which have been left out in this research. First of all, we assume that refinancing is costless. And we can consider that the exercise provides an upper bound for the effect of refinancing. This assumption also implies that different forms of refinancing have an equivalent impact on the aggregate economy. In reality, refinancing activities differ substantially in many respects, for example cost, timing and eligibility etc. Introducing different types of refinancing could help quantify the significance of each type of refinancing. Moreover, housing prices may have a substantial impact in risk-sharing and the household saving rate. Housing prices appreciation would induce even more nonhousing consumption and further reduce the saving rate, through the wealth effect. We acknowledge they are important issues and leave them to future work.

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Appendices

A Proofs

In this subsection, we prove the Lemma (1) and Results (1) and (2).

A.1 Lemma 1

Proof. Since $c_1 > 0$, it implies,

$$\widetilde{a}_1^{NR} + y_1 - \widetilde{a}_2^{NR} > 0.$$

And $a_1 = 0$ implies $\widetilde{a}_1^{NR} = -h^*$. Moreover, with assumption 1, the following holds,

$$-\widetilde{a}_1^{NR} > y_{2b} + y_1 - y_r.$$

It follows immediately that,

$$\widetilde{a}_2^{NR} < y_r - y_{2b}.$$

∎

A.2 Result 1

Proof. Given Lemma (1), we now proceed to prove our result that $\widetilde{a}_2^{NR} > \widetilde{a}_2^R$.

In the refinancing case, household solves,

$$\max_{c_1} \ u(c_1) + E\left(u\left(c_2^R\right) + u\left(c_3^R\right)\right)$$

such that

$$c_1 = \widetilde{a}_1 + y_1 - \widetilde{a}_2^R.$$

And the first order condition reads,

$$\frac{1}{2} \cdot u'\left(\frac{\left(\widetilde{a}_2^R + y_{2g}\right) + y_r}{2}\right) + \frac{1}{2} \cdot u'\left(\frac{\left(\widetilde{a}_2^R + y_{2b}\right) + y_r}{2}\right) - u'\left(a_1 + y_1 - \widetilde{a}_2^R\right) = 0.$$

In the non-refinancing case, household solves,

$$\max_{c_1} \ u(c_1) + E\left(u\left(c_2^{NR}\right) + u\left(c_3^{NR}\right)\right)$$

such that

$$c_1 = \widetilde{a}_1 + y_1 - \widetilde{a}_2{}^{NR}.$$

The first order condition reads,

$$\frac{1}{2} \cdot u'\left(\frac{\left(\widetilde{a}_2{}^{NR} + y_{2g}\right) + y_r}{2}\right) + \frac{1}{2} \cdot u'\left(\widetilde{a}_2{}^{NR} + y_{2b}\right) - u'\left(\widetilde{a}_1 + y_1 - \widetilde{a}_2{}^{NR}\right) = 0,$$

where $\widetilde{a}_2$ is an implicit function of $\widetilde{a}_1$, y_{2g}, y_{2b} and y_r, which can be treated as parameters. For convenience, we can define the following two functions:

$$g^{NR}\left(\widetilde{a}_2{}^{NR}\right) = \frac{1}{2} \cdot u'\left(\frac{\left(\widetilde{a}_2{}^{NR} + y_{2g}\right) + y_r}{2}\right) + \frac{1}{2} \cdot u'\left(\frac{\left(\widetilde{a}_2{}^{NR} + y_{2b}\right) + \widetilde{a}_2{}^{NR} + y_{2b}}{2}\right) - u'\left(\widetilde{a}_1 + y_1 - \widetilde{a}_2{}^{NR}\right)$$

$$g^{R}\left(\widetilde{a}_2{}^{R}\right) = \frac{1}{2} \cdot u'\left(\frac{\left(\widetilde{a}_2{}^{R} + y_{2g}\right) + y_r}{2}\right) + \frac{1}{2} \cdot u'\left(\frac{\left(\widetilde{a}_2{}^{R} + y_{2b}\right) + y_r}{2}\right) - u'\left(\widetilde{a}_1 + y_1 - \widetilde{a}_2{}^{R}\right)$$

$\widetilde{a}_2{}^{NR}$ and $\widetilde{a}_2{}^{R}$ are the solutions to $g^{NR}\left(\widetilde{a}_2{}^{NR}\right) = 0$ and $g^{R}\left(\widetilde{a}_2{}^{R}\right) = 0$ respectively.

Suppose by contradiction that $\widetilde{a}_2{}^{R} \geq \widetilde{a}_2{}^{NR}$. Recall lamma (1), we know immediately that,

$$\left[u'\left(\frac{\left(\widetilde{a}_2{}^{R} + y_{2b}\right) + y_r}{2}\right)\right] < \left[u'\left(\frac{\left(\widetilde{a}_2{}^{NR} + y_{2b}\right) + \widetilde{a}_2{}^{NR} + y_{2b}}{2}\right)\right],$$

Moreover, it is straightforward that,

$$\frac{1}{2} \cdot \left[u'\left(\frac{\left(\widetilde{a}_2{}^{R} + y_{2g}\right) + y_r}{2}\right)\right] - u'\left(a_1 + y_1 - \widetilde{a}_2{}^{R}\right) \leq \frac{1}{2} \cdot \left[u'\left(\frac{\left(\widetilde{a}_2{}^{NR} + y_{2g}\right) + y_r}{2}\right)\right] - u'\left(a_1 + y_1 - \widetilde{a}_2{}^{NR}\right).$$

Combing both of the inequalities, implies that,

$$g^{R}\left(\widetilde{a}_2{}^{R}\right) < g^{NR}\left(\widetilde{a}_2{}^{NR}\right) = 0.$$

which is a contradiction to the condition that $g^{R}\left(\widetilde{a}_2{}^{R}\right) = 0$. Therefore, it has to be true that $\widetilde{a}_2{}^{R} < \widetilde{a}_2{}^{NR}$. ∎

A.3 Result 2

Proof. Building on Lemma (1), we can also show that the dispersion of consumption is greater in the traditional mortgage case compared to the refinancing model. First, recall

the optimal choices of consumption in the second period for the two different regimes are:

$$c_{2g}^{R} = \frac{\left(\widetilde{a_2}^{R} + y_{2g}\right) + y_r}{2},$$

$$c_{2b}^{R} = \frac{\left(\widetilde{a_2}^{R} + y_{2b}\right) + y_r}{2},$$

$$c_{2g}^{NR} = \frac{\left(\widetilde{a_2}^{NR} + y_{2g}\right) + y_r}{2},$$

and

$$c_{2b}^{NR} = \widetilde{a_2}^{NR} + y_{2b},$$

Prove by contradiction:

$$\frac{\left(\widetilde{a_2}^{R} + y_{2g}\right) + y_r}{2} - \frac{\left(\widetilde{a_2}^{R} + y_{2b}\right) + y_R}{2} > \frac{\left(\widetilde{a_2}^{NR} + y_{2g}\right) + y_r}{2} - \widetilde{a_2}^{NR} - y_{2b},$$

which can be reformulated as,

$$\widetilde{a_2}^{R} + y_{2g} + y_r - \widetilde{a_2}^{R} - y_{2b} - y_r > \widetilde{a_2}^{NR} + y_{2g} + y_r - 2\widetilde{a_2}^{NR} - 2y_{2b},$$

$$-y_r > -\widetilde{a_2}^{NR} - y_{2b},$$

$$0 > y_r - \widetilde{a_2}^{NR} - y_{2b},$$

which contradicts Lemma (1), which states $y_r - \widetilde{a_2}^{NR} - y_{2b} > 0$ ∎

B   Computational Details

As discussed in the main text, the fact that housing stock is traded with the transaction costs is an important feature of the housing market. Transaction costs induce a "inaction zone"of the household's maximization problem. In other words, there are discontinuities in policy functions and kinks in the value functions and ex ant it is difficult to know where the discontinuities exist. We thus resort to the value function iteration method with discretization of the whole state space, which proves to be very robust. It is well known that the computing time increases exponentially, when the discretization of state space increases linearly. We make use of parallel computing techniques to speed up the policy functions computing process.

We follow the algorithm below for solving stationary equilibrium:

1. Take interest rate r as given and compute the implied aggregate capital K and the

associated wage rate w.

2. Guess the discount factor β.

3. Solve for the value function in the last period of retired households, then solve value functions recursively backwards for all the other age groups. The associated policy functions are obtained.

4. Compute the stationary distribution of households, given the policy functions from step 3.

5. Given the stationary distribution, compute the aggregate wealth-to-income ratio.

6. If the ratio is consistent with the target, then the open-economy equilibrium is found. If not, go back to step 1 and update β.