Interest-Only Mortgages and Consumption Growth: Evidence from a Mortgage Market Reform

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Abstract

We use detailed household-level data from Denmark to analyze how the introduction of interest-only mortgages affected consumption expenditure and borrowing. Four years after the reform interest-only mortgages constituted 40 percent of outstanding mortgage debt. Using an ex-ante measure of exposure motivated by financial constraints, we show households who are more likely to use an IO mortgage, increased consumption substantially following the reform. The increase in consumption is driven by borrowing at the time of refinancing and by borrowers with lower pre-reform leverage ratios. Our results show changes in the mortgage contract can have large impacts on consumption expenditure.

JEL Classification: D14, E21, G21, R21, R30;

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1 Introduction

Four years after a 2003 mortgage market reform that introduced interest-only mortgages in Denmark, these new mortgage products constituted close to 50 percent of outstanding mortgage debt and aggregate mortgage debt had increased by 40 percent.[1] This increase in debt, which is quantitatively similar to the one experienced in the United States over the same time period, occurred even though the regulatory loan-to-value ratio was unchanged and sub-prime borrowing was nonexistent and securitization did not increase. In this article, we ask how the introduction of interest-only mortgages affected the aggregate economy through its impact on consumption expenditure.

In particular, we analyze the introduction of interest-only mortgages using detailed household-level data combined with insights from recent macroeconomic models that incorporate a payment-to-income constraint for borrowing. In such models, amortization payments directly enter the borrowing constraint, which allows a reduction in monthly payments either through lower amortization payments or lower interest rates to directly influence borrowing capacity (Grodecka, 2019; Kaplan et al., 2017; Greenwald, 2018). This stands in contrast to traditional collateral-based models of credit constraints, where amortization payments do not affect borrowing directly.

We first provide an intuitive equation for when payment constraints or leverage constraints are binding. With a loan-to-value constraint and a payment constraint imposed simultaneously borrowing will be determined by the lesser of the two constraints. We use this to formulate the condition for when payments are binding: For a sufficiently high *house-value-to-income* ratio the payments on the mortgage constrain borrowing, not the value of the collateral. This simple equation has an important implication: for a household with low income but high collateral, the leverage ratio is a poor proxy for credit constraints. The reason is that even though the leverage ratio is low, any borrowing against that collateral needs to be funded out

[1] In the United States, interest-only mortgages and similar unconventional products accounted for approximately 50 percent of mortgage origination in 2007, having increased from one percent in 2000 (Justiniano et al., 2017). See also Barlevy and Fisher (2012) and Dokko et al. (2019).

of a low income.

This simple prediction fits the data on borrowing well. House-value-to-income ratios strongly predict whether households use interest-only mortgages: 62 percent of homeowners in the top quartile have an IO mortgage, compared to 32 percent in the bottom quartile.[2] Amromin et al. (2018) report similar statistics for the United States. Consistent with an interaction between two binding constraints leverage is declining in house-value-to-income ratios and interest-payments-to-income are increasing.

We proceed to estimate the impact of the introduction of interest-only mortgages on consumption expenditure of existing homeowners using their house-value-to-income ratio prior to the reform as a measure of exposure. Our empirical strategy is essentially based on a comparison between one group constrained by mortgage payments and one group constrained by leverage constraints. An extensive analysis of time trends indicates parallel trends in consumption growth prior to the reform across groups with different levels of exposure, followed by a clear break with increasing consumption growth for groups with high exposure and continued higher consumption levels. We estimate that a one standard-deviation higher house-value-to-income ratio is associated with a 5 percent increase in consumption growth. In aggregate, IO mortgages increased consumption by 8.2 percent between 2003 and 2010, corresponding to 52 percent of the total increase in consumption expenditure. The effect is driven by young households and by households with low *ex-ante* leverage. Higher leverage in 2002 is associated with a *lower* response to interest-only mortgages. While this finding does not coincide with a relaxation of a binding collateral constraint, the result is consistent with a binding PTI constraint limiting households' ability to access their collateral. Liquid wealth has little impact on the estimated effect of interest-only mortgages. Moreover, household consumption expenditure remains high even as the housing-market cycle turns and house prices decline by about 30 percent. The lack of a reversal suggests the increase in consumption after interest-only mortgages were introduced was not driven by housing-wealth effects or labor-market dynamics.

If interest-only mortgages relax borrowing constraints, we expect to see

[2]This pattern holds after controlling for a wide range of household demographic and financial characteristics.

higher borrowing at the time of refinancing (what Greenwald, 2018, calls the "frontloading effect"). We provide evidence for this effect by exploiting the timing of when the household chooses to refinance to an IO mortgage (Fadlon and Nielsen, 2015; Druedahl and Martinello, 2018). Using year and household fixed effects to address endogeneity concerns related to fixed household characteristics and business-cycle effects, we compare the behavior of households who chose to refinance to an IO mortgage in different years. The increase in consumption expenditure is almost entirely driven by higher borrowing at the time of mortgage refinancing: a spike in consumption expenditure at the time of refinancing is followed by a reversion toward the previous trend. On average, half of the increase in mortgage debt at the time of refinancing goes into consumption expenditure. The effect of introducing interest-only mortgages is therefore driven by a one-time increase in consumption at the time of refinancing, and the impact of the reform comes from a large share of the population taking out equity when refinancing to a new mortgage with lower payments.

An analysis of heterogeneous responses suggest older borrowers use the reduction in mortgage payments to increase consumption afterwards. This increase in consumption in the year after refinancing is consistent with consumption-smoothing behavior for older households who wish to live off their wealth after retirement. Older households whose retirement income is lower than their permanent income rationally wish to smooth consumption, which they can do with an IO mortgage (Cocco, 2013, argues similarly for young households with rising incomes).[3] Moreover, the increase in borrowing is lower for households with higher leverage, consistent with our aggregate-level results.

These findings are similar to the results in the literature that studies the household response to lower interest payments (Agarwal et al., 2017).[4] Bhutta and Keys (2016) find that interest payments have a substantial

[3]This requires that a household faces binding credit constraints, because households who can borrow unrestrictedly could undo any amortization payment by either refinancing their mortgage and increasing their debt (Hull, 2017), or simply borrowing more initially and using the additional funds to amortize (Svensson, 2016).

[4]See also Di Maggio et al. (2017), who find that lower mortgage payments substantially increase consumption and Cloyne et al. (2019), who show that borrowers in the United Kingdom and the United States increase their spending in response to lower interest payments.

impact on household borrowing, with an effect particularly pronounced among younger borrowers with prime credit scores.

The Danish institutional framework for mortgage financing helps rule out several other confounding factors. Mortgage debt is more strictly regulated in Denmark than in the United States, with corresponding incentives for both mortgage banks and households to not unduly speculate on rising house prices.[5] Danish mortgage banks are legally required to evaluate the income and house value for each borrower to assess whether the borrower can repay a standard 30-year fixed-rate-mortgage product even in the face of increasing interest rates. This requirement is incentivized through regulation that mandates that the mortgage banks are liable for any losses incurred on mortgage bonds by investors, even as those bonds are sold off to investors (Campbell, 2013). Other criteria for mortgage lending did not change during the boom. Mortgage borrowing is limited to 80 percent of the house value, and borrowers are evaluated on their ability to afford higher interest payments. Borrowers have a strong incentive to conform to these limits and not to overextend themselves, because all debt in Denmark is full recourse (and the laws are enforced). Indeed, Denmark experienced no default crisis, even as housing markets declined by 30 percent - mortgage arrears peaked at 0.6 percent of outstanding mortgage debt.

Our paper is related to the studies that examine consumption and borrowing for Danish households in the period around the financial crisis. Andersen et al. (2016) study how leverage in 2007 affected consumption growth between 2007 and 2009. They argue the negative relationship between leverage and consumption is the result of a spending normalization that occurs because highly levered households borrowed more on the eve of the crisis to fund consumption. Jensen and Johannesen (2017) find supply of credit to banks had a strong negative and persistent effect on the consumption of their borrowers. Kuchler (2015) finds that in 2012 households with IO mortgages have lower savings rates and higher loan-to-value ratios. Finally, two related studies examine how interest-only mortgages affect con-

[5] Brueckner et al. (2016) argue that because IO mortgages postpone repayments, the higher risk of negative equity makes this product riskier. In their model, this risk is mitigated if house-price expectations are high. Our focus on existing homeowners and the fact that default is a prohibitively expensive option in Denmark limit the concern that households are using IO mortgages to speculate.

sumption among Danish households. Larsen et al. (2018) investigates the effect of IO mortgages on homeowners in Denmark using a different data and estimation strategy. In particular, they focus on the use of funds by comparing the behavior of borrowers with and without interest-only mortgages. Overall, their study corroborates our results by showing households with IO mortgages increase their consumption and have higher mortgage debt. They do not, however, examine the macro-economic impact of the mortgage market reform. De Stefani and Moertel (2019) find that Danish homeowners with lower levels of liquid assets increased their consumption more following the introduction of IO mortgages in Denmark, which led to an increase in employment growth on the municipality level.

Overall, the introduction of IO mortgages led to a large wave of refinances, where households who refinanced also extracted equity. This one-time adjustment in the mortgage market, where a substantial fraction of mortgage debt is refinanced can have a large impact on consumption growth. In general, our study illustrates the importanceof payment constraints in the mortgage market and provides evidence on how changes in the mortgage market affect macroeconomic outcomes. These findings are important not only for characterizing the boom-bust episodes in Denmark, the United States and elsewhere, but also for policies that guard against future crises. In particular, our results suggest a framework for analyzing the impact of macroprudential policies on the cross-section of households, and suggest such policies can have a large impact on borrowing and consumption. Finally, we note that the long-term effects of this reform are yet to be determined and warrant future research.

2 Background

2.1 The Danish Mortgage Market

The predominant mortgage contract in Denmark has historically been the 30-year fixed-rate mortgage, which made up over 90 percent of outstanding mortgages in the early 2000s.[6] This maturity is the longest and the most

[6]Danish mortgage-credit banks provide mortgage loans to households and sell bonds to investors using the payments from the mortgage loans. The mortgage system operates

popular one. Variable-rate mortgages were introduced in 1997. The interest rate on mortgages is decided not by the mortgage bank, but by investors in mortgage bonds.

All borrowers can refinance with no pre-payment penalty, regardless of their equity position. In other words, there is no lock-in effect of housing equity. Households can refinance to extract home equity up to the maximum loan-to-value limit of 80 percent. This requirement is enforced throughout our sample period for all types of mortgages. The cost for refinancing is approximately 10,000 DKK ($1,500) (Andersen et al., 2019). Borrowers are evaluated on their ability to afford a standard 30-year fixed-rate mortgage regardless of the mortgage contract they choose, and all mortgage debt is full recourse. In case of a borrower default, the mortgage bank can enact a forced sale of the collateralized property. If the proceeds from the sale are insufficient to cover the outstanding debt, the mortgage bank can garnish the incomes of the borrower until the debt is repaid. These design features ensure that no strategic incentive to default exists in Denmark, regardless of the equity position.

In addition, mortgage banks are required to assess the credit risk of the borrower, and have to maintain all credit risk on their balance sheet. Mortgage-credit banks use the proceeds from their borrowers to issue mortgage-backed bonds to investors. Mortgage banks receive fees from borrowers but do not receive interest income and mortgage payments, which instead accrue to the bond investor. To limit moral hazard, mortgage-credit banks are legally required to retain all credit risk on their balance sheets. If a borrower defaults, the mortgage bank has to replace the defaulting mortgage with a bond with an equivalent interest rate and maturity. Investors therefore bear all refinancing and interest-rate risks, but face no credit risk. This system operates without government intervention or direct guarantees.

according to a "matched funding" principle, where each mortgage loan is matched by a mortgage bond sold to investors. A more comprehensive overview can be found in Campbell (2013, p. 28) and Kuchler (2015).

2.2 Interest-only mortgages in Denmark

Interest-only mortgages were introduced in Denmark in 2003 through a regulatory reform.[7] The regulatory framework specifically details which mortgage products the mortgage banks are allowed to offer their customers. The purpose of the reform was to increase affordability and flexibility for temporarily credit-constrained households. The expectation was that IO mortgages would be a niche product with no impact on house prices or consumption.[8] The legislation that allowed the mortgage banks to offer interest-only mortgages, referred to in Denmark as a "deferred amortization" mortgage (*afdragsfrie lån*), was introduced to the Danish parliament on March 12, 2003 and was voted through parliament on June 4. Mortgage banks could start selling interest-only mortgages as early as October 2003. The new product allowed for a 10-year period without amortization payments, after which the borrower had to repay the outstanding debt over the remaining life-span of the mortgage.

Due to higher principal debt over the first 10 years, total interest-payments over the life-span of the loan are higher for an interest-only mortgage than for an amortized mortgage. The law proposal specifically mandates the mortgage banks inform their customers about the higher cost and higher risk associated with IO mortgages. In 2011, 89 percent of surveyed IO-loan holders reported being "very well informed" or "well informed" about the higher cost and higher risk associated with their mortgage choice (Association of Danish Mortgage Credit Banks, 2011).

Interest-only mortgages rapidly became a popular product. Figure 1 shows close to a third of *outstanding* mortgage debt in Denmark was held in interest-only mortgages three years after the reform. Interest-only mortgages are prominently used in areas with high house prices, such as Copenhagen or other larger cities, but are also popular in other areas. Examining

[7] Technically, a bank customer could approximate an interest-only mortgage prior to the reform by either continuously refinancing (Hull, 2017) or by extracting more equity and using excess funds to pay the amortization payments. Consequently, the reform can be seen as allowing for an easier and less expensive way of taking out an interest-only mortgage product.

[8] Additional material on the process, the motivation and the debate surrounding the introduction of IO loans can be found at https://www.retsinformation.dk/Forms/R0710.aspx?id=91430 and http://webarkiv.ft.dk/Samling/20021/MENU/00766131.htm.

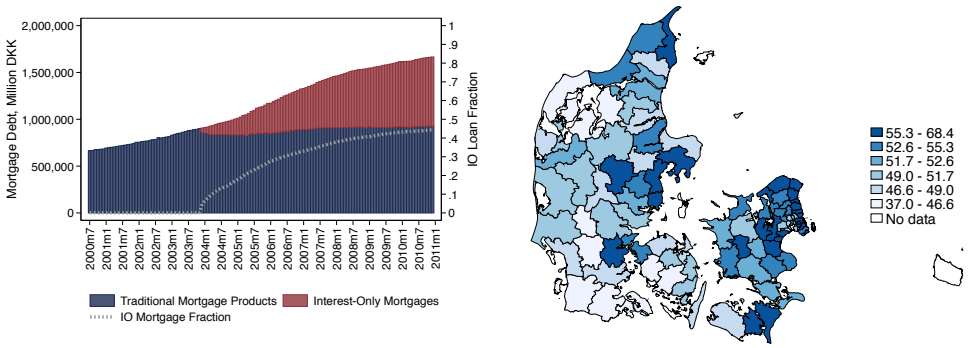


Figure 1: IO Mortgage Penetration

Notes: The figure on the left plots outstanding mortgage debt in DKK divided into traditional amortizing mortgages and interest-only mortgages, from Nationalbanken. The grey line plots the fraction of all outstanding interest-only mortgages. The figure on the right plots the share of IO mortgages in each municipality using data from 2009.
Source: Nationalbanken

Danish municipalities (approximately equivalent to a US county) for 2009, the right-hand side of Figure 1 shows the lowest penetration is 37 percent and the highest one is close to 70 percent. This pattern of mortgage use is somewhat in contrast to evidence from the United States, where Amromin et al. (2018) and Barlevy and Fisher (2012) report that IO mortgages were prominent in areas where house price growth was high but not elsewhere.

The Danish housing decline and following recession did not reduce the popularity of these products, in contrast to how the use of similar products evolved in other countries. Barlevy and Fisher (2012) and Amromin et al. (2018) find that IO mortgages in the United States essentially disappeared after the housing crash. Cocco (2013) documents that IO mortgages in the UK became less prominent after a regulatory change in 2000. Even though Danish house prices declined by a similar magnitude as in the United States, these products remain popular and in use today.

3 Data and Variables

Denmark Statistics provides data on wealth, income, and demographic characteristics for the entire population of Denmark. The data are collected through third-party reporting and are highly reliable, accurate, and comprehensive. We collapse the individual-level data to the household level using a unique family identifier. We then construct a panel of households

taking information on demographics such as age, gender, education, marital status, the number of children, and municipality of residence; disaggregated asset and debt information such as stock and bond holdings, cash deposits in banks, bank debt, and the market value of mortgage debt; labor-market information such as disposable income, wages, and employment status; housing information including ownership status, property value, number of properties, and housing-market transactions. The oldest (most educated) member of a household determines the age (education level) of the household.

An important variable for our analysis is the *house-value-to-income* ratio. We construct this variable for each household using adjusted tax-assessed house values divided by disposable income. Administrative data systematically underestimates actual house value, and we therefore adjust it using a scaling factor. The scaling factor is a ratio between the actual sales price and the tax-assessed valuation for all housing transaction in a given year. We then average the scaling factor for each year-municipality cell and multiply the tax-assessed house value for each household based on the municipality of residence.[9] Finally, we divide this measure by disposable income to obtain house-value-to-income ratio.

We construct two variables related to credit constraints. First, we measure liquidity constraints based on the ratio of the sum of stocks, bonds and cash deposits, and disposable income. Following Browning et al. (2013), we create a dummy equal to one if liquid assets are less than 1.5 months of income. Second, we measure collateral constraints based on the ratio of the value of outstanding mortgage debt and housing wealth, which we refer to as leverage, or loan-to-value (LTV). We construct dummies for deciles of leverage, and a dummy equal to one if the LTV ratio is above 0.5.

Our key outcome variable is consumption expenditure, and we impute it using observed information on income and changes in wealth. Consumption spending in a given year is constructed as disposable income minus the change in net wealth. This procedure has been used in numerous empirical studies using Danish data (see, e.g., Leth-Petersen, 2010; Browning et al.,

[9]Denmark Statistics calculates the equivalent scaling factor, but we are unable to use theirs because of the municipality reform in 2007. For the years when we can compare our scaling factor to the one provided by Denmark statistics, the two are consistent.

2013; Jensen and Johannesen, 2017). More importantly, imputed consumption expenditure has been validated by comparing it to survey measures, and has generally performed well on average (Browning and Leth-Petersen, 2003; Kreiner et al., 2015).[10] Jensen and Johannesen (2017) compare an aggregated measure of consumption imputed from Danish registry data to the value of private consumption in the national accounts, and show the trend in the two measures is very similar from 2003 to 2011. Browning and Leth-Petersen (2003) find imputed consumption corresponds well to the self-reported consumption on average, but that outlier values can be problematic.[11] We winsorize consumption expenditure at the 1st and 99th percentile. Finally, we limit the sample to households who are present during all relevant years (from 2000 to 2010, a total of 11 periods).

The main concern with imputed consumption is that changes in the valuation of items on the balance sheet, such as unrealized capital gains on stock portfolio, will be measured as consumption. Also, an increase in the interest rate will lead to a decrease in the market value of a fixed-rate mortgage, increasing net wealth and lowering consumption expenditure. Controlling for unrealized capital gains is not an issue for housing, where we can observe all property transactions. As we focus on homeowners who do not change their residence, we remove households who trade housing from the sample and do not include changes in housing wealth in the imputation.

To address concerns over the stock portfolio (Koijen et al., 2015), we approximate capital gains on stock portfolios with the market-portfolio return. Specifically, we multiply the value of stock holdings at the beginning of the year with the over-the-year growth in the Copenhagen Stock Exchange (OMX) C20 index, and calculate active savings as the end-of-year holdings minus stock holdings at the beginning of the year adjusted for the capital gains.

We supplement our data with detailed information about mortgage-debt characteristics. Mortgage data are provided annually by Finance Denmark starting in 2009, and contain information from the five largest mortgage

[10] See also Koijen et al. (2015) for a similar procedure using Swedish data, and Ziliak (1998), Cooper (2013), and Khorunzhina (2013) for imputed consumption using survey data.

[11] Koijen et al. (2015) point to a similar issue for consumption imputed from Swedish administrative data.

banks in Denmark with a total market share of more than 90 percent.[12] We use the origination date to assign the mortgage type for the years before 2009. Specifically, we aggregate loan values and other characteristics based on the origination year of the mortgage, and then merge these characteristics to households prior to 2009.[13] For each mortgage, we observe loan size, bond value, maturity, the origination date of the mortgage, whether it is an interest-only loan, and whether the mortgage has a fixed interest rate. We also observe a unique loan number, which can be shared between several individuals. Because we observe the total loan size and not the individual's share of the mortgage, we calculate an equal weight based on the number of individuals with the same loan number. For example, if a mortgage loan occurs twice in the data, we assign half the loan value to each individual. We then aggregate the individual data to the household level using the family identifiers described above.

Following a related study of Browning et al. (2013), we select households between ages 22 and 55 who own housing.[14] We remove all entrepreneurs, because their income and wealth characteristics are less accurately reported, and we remove households who trade their residential housing during the sample period.

Summary Statistics

Table 1 provides summary statistics for households for the year 2002, the year prior to the reform. We report statistics by mortgage type, which is observed in 2009. We report demographic and financial characteristics for households who refinanced to IO mortgages by 2009 in column (1), and who had a traditional, amortizing mortgage in 2009 in column (2). Demographics include age, years of education, family size, and the employment ratio during the year. Financial characteristics include house-value-to-income, liquid-assets-to-income, mortgage-to-income, and interest-payments-to-income. Mortgage rate is the sum of mortgage in-

[12] See Andersen et al. (2019) for more information about the registry.

[13] With this procedure, we cannot fully classify whether a mortgage is interest-only in the years prior to the most recent refinancing. The match worsens as we go further back in time, because households may refinance to take advantage of lower interest rates.

[14] We have also used a sample of individuals instead of households. The results are very similar and our conclusions are unchanged.

Table 1: Summary Statistics for Households in 2002 prior to the Reform by ex-post Mortgage Choice

	IO Mortgage (1)	Traditional Mortgage (2)	Difference Highest-Lowest (3)
Household Demographic Characteristics			
Age	45.49	45.05	-0.43***
	(6.60)	(6.31)	[-11.05]
Education Length	14.47	14.42	-0.06***
	(2.09)	(2.10)	[-4.34]
Family Size	3.29	3.24	-0.05***
	(1.21)	(1.20)	[-7.46]
Employment Ratio during the Year	0.97	0.97	0.00*
	(0.08)	(0.08)	[2.36]
Financial Characteristics			
Housing Wealth to Income	3.92	3.45	-0.48***
	(1.60)	(1.36)	[-53.73]
Liquid Assets to Income	0.23	0.28	0.05***
	(0.42)	(0.43)	[17.89]
Mortgage to Income	2.36	1.86	-0.51***
	(1.03)	(0.89)	[-87.62]
Mortgage Rate	0.06	0.07	0.01***
	(0.02)	(0.03)	[37.03]
Interest Payments to Income	0.13	0.11	-0.02***
	(0.05)	(0.05)	[-75.28]
Liquidity Constrained	0.55	0.45	-0.10***
	(0.50)	(0.50)	[-33.10]
Borrowing Constrained	0.79	0.68	-0.11***
	(0.41)	(0.47)	[-41.63]
Consumption growth 2002-2006	0.14	0.09	-0.05***
	(0.51)	(0.46)	[-17.55]
Income growth 2002-2006	0.03	0.05	0.02***
	(0.19)	(0.16)	[22.74]
House Price Growth 2003-2006	39.42	35.19	-4.23***
	(15.04)	(14.98)	[-46.36]
Households	44,633	68,643	113,276

Notes: We report descriptive statistics for households' demographic and financial characteristics by mortgage choice for 2002 for households who refinanced to IO mortgage by 2009 (column (1)), and who had a traditional, amortizing mortgage in 2009 (column (2)). Column 3 reports the differences between columns 1 and 2, including the results from a t-test for differences. Liquidity constrained is a dummy equal to one if liquid assets are less than 1.5 months of income, and borrowing constrained is a dummy equal to one if mortgage value divided by house value is greater than 0.5. Standard deviations are in parentheses. ***, **, * denote significance at the 1%, 5%, and 10% for the t-test.

terest payments divided by the market value of the mortgage. Liquidity constrained is a dummy equal to one if liquid assets are less than 1.5 months of income, and borrowing constrained is a dummy equal to one if mortgage value divided by house value is greater than 0.5. House-price growth is defined as the percentage growth in square-meter prices from 2003 to 2006. Personal-income growth is the percentage growth in income from all sources.

We find higher mortgage-to-income and interest-payments-to-income, and a larger share of households facing liquidity and borrowing constraints prior to refinancing among those with an IO mortgage. Also, IO mortgage holders experienced lower income growth, faster consumption growth, and higher house-price growth over the housing market boom period.

4 Conceptual Framework

In this section, we consider how household consumption may respond to a relaxation of borrowing constraints induced by an IO mortgage. We focus on households-homeowners, who possibly have a mortgage debt and may choose refinancing to an IO mortgage once it becomes available. A useful starting point is to consider a household that can borrow freely, and consumes without restrictions. An unconstrained household can set a desired consumption path, borrow when current resources are low relative to lifetime resources, and pay down debt when current resources are high relative to permanent resources.[15] Absent any shocks, a relaxation of borrowing constraints through an IO mortgage should not affect consumption, becuase the household already could borrow and consume as much as desired.[16]

For borrowing-constrained households, a relaxation of a constraint can induce higher consumption through higher borrowing if consumption is below the desired level. The typical way of modeling this relaxation of borrowing constraints in the macroeconomic literature is to relax a loan-to-value constraint, where borrowing is constrained by collateral value (see Guerrieri and Uhlig, 2016, for a comprehensive overview). A loan-to-value constraint allows the household to borrow an amount M up to a fraction θ_H of house value H:

$$M \leq \theta_H H.$$

[15] In a model of consumption with an amortization requirement, Svensson (2016) shows that although consumption remains constant with higher amortization payments, as long as the interest rate for borrowing rate is equal to the interest rate on savings, borrowing may actually increase for unconstrained households, because households borrow more to compensate for the higher amortization payments.

[16] Here we are abstracting from precautionary savings, which the household may reduce if credit is easier to access.

Relaxing the above constraint involves either a higher collateral value H or a higher LTV limit θ_H. If the household faces only this constraint an interest-only mortgage will not affect borrowing, because amortization payments are not a part of the constraint.

Recent models have instead turned towards *payment-to-income* constraints, where borrowing is limited by mortgage payments (Greenwald, 2018; Kaplan et al., 2017). A PTI constraint limits borrowing by restricting interest payment r_m and amortization payments γ to a fraction θ_Y of income Y:

$$M(\gamma + r_m) \leq \theta_Y Y. \tag{1}$$

Relaxing this constraint involves either a higher PTI limit θ_Y, higher income, or a lower mortgage payment. Although the focus has mainly been on lower interest payments (and a higher PTI limit; see, e.g., Greenwald, 2018), the amortization payments have an equivalent effect. For instance, a household with a mortgage interest rate of 5 percent and a 3 percent amortization rate that wishes to keep mortgage payments below 20 percent of income is limited to borrowing at most 2.5 times her current income. If amortization payments were removed, borrowing can increase to four times income.[17] A similar increase in maximum borrowing would occur if the mortgage rate were reduced to 2 percent.

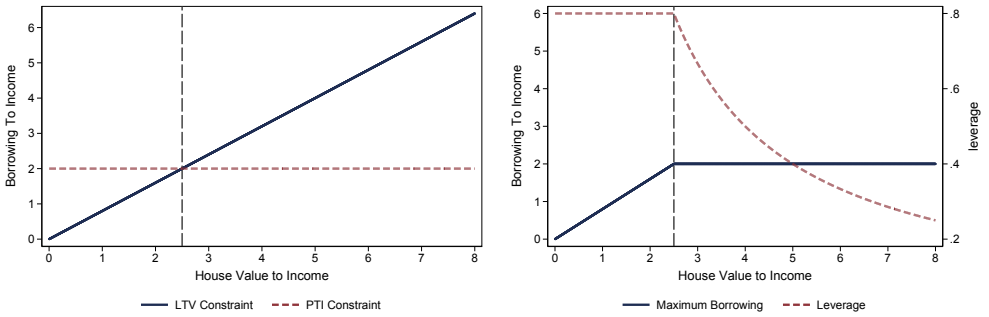
For a constrained household an interest-only mortgage increases borrowing if the PTI constraint is binding. Conversely, an interest-only mortgage does not affect borrowing if the LTV constraint is binding. The key question to understanding how IO mortgages affect borrowing and consumption is which constraint is active. We can rewrite the above constraints as:

$$\bar{M}^{ltv} = \theta_H H \qquad \text{and} \qquad \bar{M}^{pti} = \frac{\theta_Y Y}{(\gamma + r_m)},$$

where $\bar{M}^{ltv}$ and $\bar{M}^{pti}$ denote the maximum borrowing given the LTV and PTI constraint, respectively. For a borrower who has to fulfill both constraints simultaneously, the minimum of these two terms will determine borrowing. We can write the overall debt limit as $\bar{M} = \min(\bar{M}^{ltv}, \bar{M}^{pti})$.

[17] Borrowing to income in the initial example is equal to $0.20/(0.05 + 0.03) = 2.5$. With lower amortization payments, the borrowing capacity is equal to $0.20/0.05 = 4$ times income.

Figure 2: Borrowing under Two Constraints



(a) Borrowing with a PTI and LTV Constraint

(b) Maximum Borrowing and Leverage

Notes: We set the interest rate to 7 percent and amortization payments to 3 percent,. We set the LTV constraint θ_H equal to 0.8 and the PTI constraint θ_Y equal to 0.2. Both house values and borrowing are divided by income.

Because household borrowing capacity is subject to both constraints simultaneously, borrowing capacity is determined by the lower of the constraints. In other words, the PTI constraint will be binding if $\bar{M}^{pti} < \bar{M}^{ltv}$, or:

$$\frac{\theta_Y Y}{(\gamma + r_m)} < \theta_H H.$$

Rearranging, we get an expression for when the PTI constraint is binding:

$$\frac{H}{Y} > \frac{\theta_Y}{\gamma + r_m} \frac{1}{\theta_H}. \tag{2}$$

From above, if a household is facing borrowing constraints, the PTI constraint is binding for sufficiently high values of H/Y. Intuitively, for sufficiently high H/Y, the payment for borrowing is binding and not the value of the collateral. Even if collateral value is high enough that the LTV constraint is not binding, the household is unable to take advantage of higher collateral and cannot borrow more.

We illustrate this result in Figure 2, where we plot borrowing according to each constraint in panel (a) and the maximum borrowing in panel (b). House value and borrowing are both scaled by income. Following the institutional framework in Denmark, we set θ_H to 80 percent of house

value, and θ_Y to 20 percent of income.[18] The LTV constraint implies that maximum borrowing is linear in collateral values – as the house-value-to-income ratio increases, so does maximum borrowing. The LTV constraint is represented by the blue line, where the slope is equal to θ_H. The PTI constraint is represented by the red dashe line. This constraint is not affected by the value of the collateral – the PTI constraint is constant over H/Y. With an interest rate of 7 percent and amortization payments of 3 percent, maximum borrowing is equal to 2 times the income.

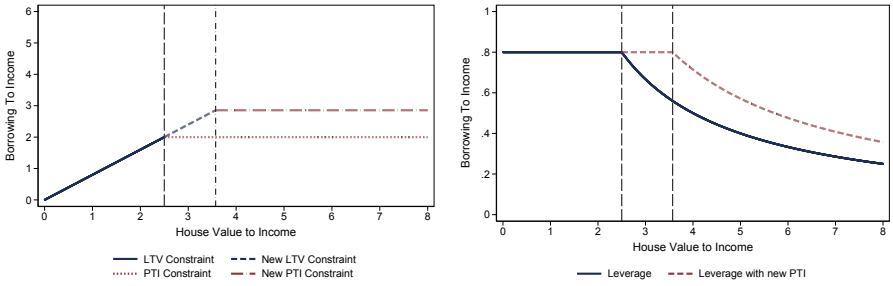
In part (b) of Figure 2 we plot maximum borrowing according to each constraint, where the overall borrowing constraint switches from the LTV constraint to the PTI constraint at the threshold in equation (2). For all values of H/Y above 2.5, the PTI constraint is binding, which is indicated by the dashed vertical line in Figures (a) and (b).[19] Whereas the collateral values are sufficient to meet the LTV constraint, the payment on any borrowing above the level of 2.5 will not satisfy the PTI constraint. Conversely, for H/Y below 2.5, the collateral constraint is binding and the household can only borrow 80 percent of the collateral value, even though the PTI constraint is slack. The household is not fully using her collateral above the H/Y value of 2.5. In addition, the leverage (borrowing divided by house value) is declining in H/Y. As the PTI constraint becomes binding, the household is unable to borrow against collateral and the leverage falls.

Now consider what happens with borrowing under the two constraints when interest-only mortgage becomes available. In Figure 3, we plot the change in borrowing as the amortization payment is set to zero, and the maximum borrowing capacity of a household constrained by the PTI constraint increases. This is illustrated by a shift of the red dashed line. For values of H/Y below 2.5 times income, borrowing does not change. For these households, removing amortization payments has no impact on borrowing. For values above 2.5, however, borrowing increases. For some house-value-to-income the binding constraints switch from PTI to LTV, creating an angled upward slope of the red dashed line. Borrowing is therefore increasing in H/Y, although the effect is non-linear in three sections

[18] Formally, there is no PTI constraint in the Danish institutional framework, although mortgage banks seem to enforce this constraint if we examine the data. The LTV constraint is set by law.

[19] The PTI constraint is binding if H/Y is greater than $0.2/(0.07+0.03)\times 1/0.8 = 2.5$.

Figure 3: Borrowing under Two Constraints



(a) Maximm

(b) Maximum Borrowing and Leverage

Notes: The interest rate is 6 percent and amortization payments are 2 percent of mortgage debt, and the collateral constraint, θ_H, is equal to 0.8 and is the slope of the LTV constraint. Both house values and borrowing are divided by income.

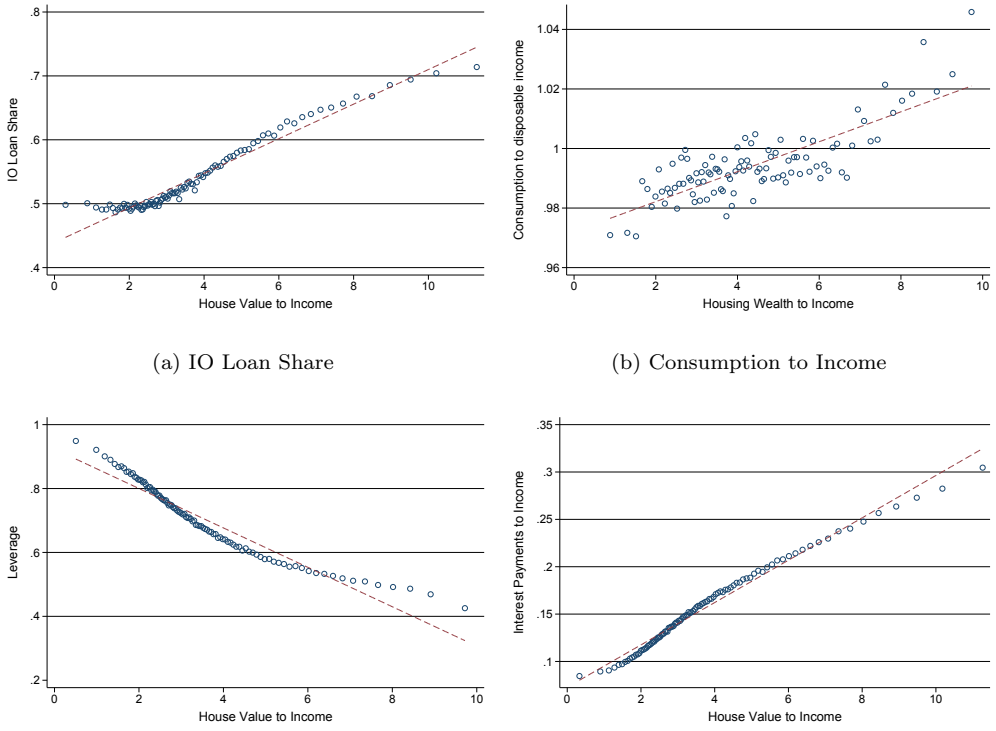
of the H/Y values: (1) zero when the LTV constraint is binding; (2) equal to the borrowing constraint on the LTV ratio between the new and old threshold values due to a constraint switching effect; and (3) equal to the increase in the PTI limit if the LTV constraint does not start to bind. The switch from the PTI constraint to the LTV constraint in the second part of the H/Y distribution is emphasized in Greenwald (2018), and implies certain households are not able to take full advantage of the potential increase in borrowing. Moreover, the full advantage from the potential increase in borrowing can only be available to households with values above the new threshold.

Figure 9 in the appendix shows how borrowing changes when the LTV ratio is changed. Borrowing increases if the LTV constraint is binding, but the higher maximum LTV ratio also makes the PTI constraint tighter. Effectively, this result arises because the borrower is able to borrow more against the collateral, which means the PTI constraint becomes binding faster.

Empirical support for two borrowing constraints

Our conceptual framework has some predictions that are validated in the data. First, if IO mortgages can relax the binding PTI constraint and this effect can be predicted by H/Y, then IO mortgages would be increasing in H/Y. Panel (a) in Figure 4 shows that this prediction is born

Figure 4: IO loan share, consumption to income, leverage, and interest payments to income against the house-value-to-income ratio



(a) IO Loan Share

(b) Consumption to Income

(c) Leverage

(d) Interest Payments to Income

Notes: All bins control for year of origination and municipality fixed effects.

out in the data: the house-value-to-income ratio in 2002 strongly predicts subsequent IO mortgage use. The figure plots the loan share against the house-value-to-income ratio measured in 2002, showing a strong positive correlation between the IO mortgage share and house-value-to-income ratio for binned bivariate averages, or "binscatters'.'[20] Second, the figure shows the consumption-to-disposable-income ratio is increasing in house-value-to-income ratio, which suggests consumption rate is higher for households with a high house-value-to-income ratio. The higher spread around the line in panel (b) indicates more variation within each bin, showing the presence of heterogeneity in consumption-to-disposable-income across house-value-to-income ratios. Third, we plot leverage over H/Y in panel (c). This pattern is consistent with binding payment-to-income constraints

interacting with collateral constraints as in Figure 2(b). Borrowers with high house-value-to-income ratios who face two constraints are unable to borrow against their home equity, and thus leverage is lower.

The conceptual framework also predicts that interest payments are increasing in H/Y (see Figure 10 in the appendix), but that the curve becomes flat as the borrower hits the PTI constraint. The figure in panel (d) does not fully support this prediction, instead showing that interest-payments-to-income continue to increase with house-value-to-income ratio. However, according to panel (a), the IO mortgage share is also increasing in H/Y. If borrowers can substitute amortization payments for interest-payments, interest-payments-to-income continue to increase in H/Y, albeit at a slower pace. This is indeed what the figure shows. A regression analysis (not reported) confirms the coefficient on H/Y on interest payments is smaller for values of H/Y higher than 4. The difference in the coefficients is statistically significant.

Overall, a framework with both PTI and LTV constraints generates clear predictions for borrowing that correspond well to the data.

5 The Impact of IO Mortgages on Consumption Expenditure

We use two different methodologies to estimate the impact of IO mortgages on consumption and borrowing. Because we cannot perfectly observe who holds an IO mortgage before 2009, and because the decision to refinance to IO mortgage may be correlated with other variables that drive consumption growth, we begin with a strategy that leverages an *ex-ante* measure of exposure to IO mortgages in an *intent-to-treat* analysis.

[20]The results are robust to excluding any controls and to focusing on mortgage originated between 2004 and 2006, if we use loan size at origination or loan-to-income values, if we focus only on mortgage originated in the housing boom, if we use municipality-level data, if we split the sample into households up to 40 or above, and if we focus on the sample that we use in the estimation.

5.1 Empirical Strategy

Using the measure of exposure to IO mortgages, we follow the conceptual framework in section 4 in estimating the effect of relaxed borrowing constraints on consumption expenditure. Specifically, we use the pre-reform house-value-to-income ratio to identify households who are more likely to face binding PTI constraints, and who are therefore more likely to benefit from IO mortgages. Our empirical strategy exploits the cross-sectional variation in the *ex-ante* house-value-to-income ratios ("Exposure") to isolate the effect of the new mortgage product on household consumption expenditure. By ranking households prior to the reform, we also avoid households selecting into high house-value-to-income ratios in anticipation of the reform. Berger et al. (2016) and Mian and Sufi (2012) use a similar strategy to estimate the causal effect of a national policy on groups with various treatment intensity.

We estimate the following regressions:

$$\frac{Consumption_{i,\tau \to T}}{Consumption_{i,2000}} = \alpha + \beta Exposure_i \times \tau + \gamma X_i + \delta_\tau + \epsilon_{i,\tau}, \qquad (3)$$

where $Consumption_{i,\tau}$ is consumption expenditure for household i in time periods τ and $Exposure_i$ is the house-value-to-income ratio in 2002zero mean and unit variance. We scale consumption by its value in 2000 to estimate growth rates, similar to Berger et al. (2016). By scaling consumption expenditure by its 2000 value instead of using year-over-year changes, we reduce the noise and additionally avoid equity extraction in one year from unduly affecting consumption growth.[21] All control variables are measured in 2002, and we cluster standard errors at the municipality level.

Although the IO mortgage share is strongly correlated with the exposure variable, a valid concern is that characteristics unrelated to IO mortgages are driving differences in consumption growth for low- versus high-exposure

[21] Andersen et al. (2016) show households with high values of consumption in 2007 experienced large declines in the next-year consumption because of mean reversion following equity withdrawal. If a household borrows (extracts equity), consumption expenditure in that year will be high due to the imputation procedure. The next year, however, consumption will be low, because the household is not likely to extract equity again. Year-over-year growth rates in consumption expenditure will therefore first be high and then negative.

households. For example, areas with higher IO-loan penetration may experience higher income growth over the business cycle, leading to differential trends in income growth and thereby consumption. Further, the introduction of IO mortgages may lead to changes in homeownership over the cycle, as households adapt their housing choice to the newly available mortgage choice. To address the last issue, we measure house-value-to-income prior to the mortgage reform to ensure our measure is not conflated with homeownership decisions later in the business cycle. Table 4 in the Appendix reports summary statistics for households in different groups of Exposure, showing significant differences between households depending on exposure. Importantly, the house-price growth is different for groups with high and low exposure, income growth is not substantially different, and the mortgage rates are statistically but not economically different.

We further employ multiple additional strategies to address these concerns. First, we use growth rates in consumption instead of levels, thereby removing differences caused by different income or consumption levels. Second, we provide extensive tests for parallel trends in the pre-treatment period. Third, we explicitly control and test for housing wealth effect, as house-price growth is higher for household with higher. Fourth, our results are robust to including controls for income growth, changes in mortgage rates and municipality fixed effects to control for income shocks at the local level. All these results increase our confidence that we are identifying the causal effect of IO mortgages on consumption.

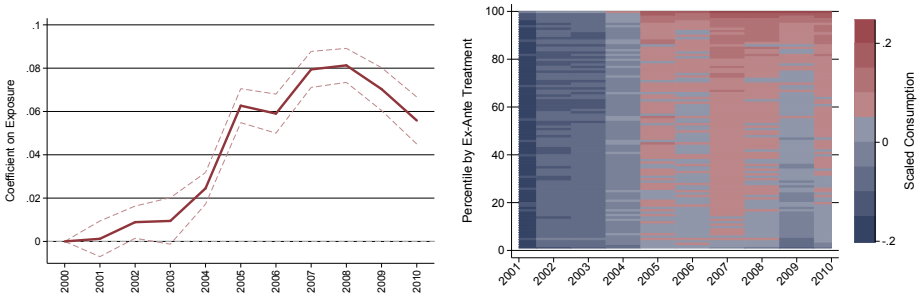
5.2 Main Results

First, we show our main result graphically. Figure 5(a) plots the coefficients on *Exposure* interacted with the year dummies in a regression (3). The coefficient on Exposure is estimated close to zero and not statistically significant for 2001 - 2003, but is positive and statistically significant after the introduction of IO mortgages. Consumption expenditure increases more for households with higher ex-ante exposure to IO mortgages, a result that does not reverse over time, even after house prices start decreasing in 2008 and 2009. This pattern is not consistent with short-term shocks affecting consumption, such as business-cycle effects, income expectations or

Figure 5: Consumption Expenditure by Exposure

(a) Consumption Expenditure by Exposure

(b) Heatmap



Notes: Figure (a) plots the coefficients on *Exposure* from regression (3), and the 95 percent confidence intervals, marked with dashed lines. Control variables include dummies for age, family size, and education level. Standard errors are clustered on the municipality level. Figure (b) plots a difference-in-difference, year-by-year heatmap of consumption expenditure. The vertical axis sorts households into 100 bins based on $Exposure_i$, and the horizontal axis shows years. Each cell color corresponds to the level of the outcome variable (consumption scaled by the value of consumption in 2000) after we partial out control variables.

housing-wealth effects, as those would revert back once the economy and housing market start declining in 2007.

Next, we present evidence on the effect of higher Exposure on consumption growth in Figure 5(b), following Berger et al. (2016). The figure plots scaled consumption for 100 bins based on pre-reform house-value-to-income. The vertical axis shows households sorted by their 2002 house-value-to-income ratios, and the horizontal axis indicates year. A higher value on the vertical axis corresponds to a higher house-value-to-income ratio in 2002 (a higher Exposure). Each cell shading shows the value of consumption scaled by its year 2000 value. This approach allows for performing the traditional graphical pre-trend comparisons between different groups for the population distribution. Each cell corresponds to the trend in consumption growth for a specific group, where we can use the relative shading prior to the introduction of IO mortgages in 2003 to examine different pre-trends in consumption growth.

Prior to the introduction of IO mortgages in late 2003, consumption growth is similar across groups, indicating parallel trends in consumption growth, and suggesting the assumption behind the empirical strategy is valid. After 2004, consumption increases for the households who benefit the most from the reform. Consumption growth in 2005 appears to be

Table 2: Consumption by Exposure for Different Time Periods

	No Controls (1)	Dem.Controls (2)	Inc & Mortgage Rate (3)	Low HP growth (4)
Pre-Reform×Exposure	-0.001	0.007*	-0.006	-0.007*
	(0.004)	(0.003)	(0.004)	(0.003)
Early Post-Reform×Exposure	0.041***	0.049***	0.019***	0.016***
	(0.004)	(0.003)	(0.004)	(0.004)
Late Post-Reform×Exposure	0.064***	0.072***	0.033***	0.031***
	(0.003)	(0.003)	(0.003)	(0.003)
Observations	1,517,471	1,514,460	1,489,933	1,317,044

Notes: The table presents estimates of the per-period effect of Exposure on consumption growth from cross-section regression (3), where Exposure is normalized to zero mean and unit variance. All regressions include municipality dummies. Column (2) includes age, family sizes, and education as control variables. In Column (3) we control for a household-specific mortgage rate for the period and disposable-income growth. Column (4) removes households in the top quartile of house-price growth, calculated as the increase in square meter prices from 2002 to 2006. *, **, *** denote statistical significance at the 5%, 1% and 0.1% level. Standard errors clustered on municipality in parentheses.

monotonically increasing in the ex-ante benefit of choosing an IO mortgage, showing the results are not driven by outliers. Moreover, the impact of IO mortgages is seemingly not short-lived. This observation is consistent with a higher consumption level or conversely a lower savings rate. It is also consistent with higher exposure leading to a higher likelihood of refinancing to extract equity in each year. If individuals with higher exposure are more likely to refinance compared to individuals with low exposure this would lead to higher consumption growth for for groups with higher exposure once we aggregate individuals into groups. Additionally, this observation is not consistent with cyclical factors such as house-price growth or temporary income shocks that reverse once house prices decline starting in 2007 and the labor market turns.

Table 2 provides the estimates of a regression of exposure on consumption scaled by its 2000 value over different time periods, formulated in equation (3). We estimate equation (3) over three time periods: a pre-reform period from 2000 to 2002, an early post-reform period from 2003 to 2006, and a late post-reform period from 2007 to 2010. We divide the post-reform period into an early and late periods to examine whether different house-price regimes affect the results. The results in this table confirm the results in the previous figures for a variety of specifications. In the pre-reform period, we find no significant coefficient on exposure. Even after

we include various controls, the coefficient on exposure for the pre-reform period is either very small or not statistically significant. Consistent with the results in the above figures, Exposure predicts higher consumption for the post-reform period. The results in column (1) and (2) with or without demographic controls indicate a 4.1 to 4.9 percent increase in consumption relative to its 2000 value for a one standard deviation increase in Exposure in the years immediately after the reform, and a 6.4 to 7.2 percent increase for the period of 2007 - 2010. Therefore, consumption expenditure is consistently higher for households with higher values of exposure, and shows no sign of reversing when house-price growth turns negative in 2008 - 2009.

However, other factors correlated with exposure could drive consumption growth. In particular, lower interest rates and higher income growth can potentially cause higher consumption. Lower interest rates would also affect the PTI constraint in a similar manner to an IO mortgage. If the PTI constraint is binding, a variable-rate mortgage with a lower interest rate would also allow for higher borrowing. Similarly, higher income growth relaxes the PTI constraint and allows for higher consumption. To address these concerns we control for the per-period interest rate and disposable-income growth in column (3) of Table 2. The effect is reduced in magnitude but qualitatively not changed. In column (4), we exclude households living in municipalities in the top quartile of high house-price growth during housing boom (2004-2007). The coefficients are reduced in magnitude but remain significant.

We also test whether groups that are more or less likely to be financially constrained reacted differently to the introduction of interest-only mortgages. The results are available in Table 3 for the pooled-sample period (2004-2010). In all regressions we control for the variable of interest and interpret the results of the interaction as an additional effect of higher exposure for a particular group.We examine two proxies for financial constraints: liquid-assets-to-income (Liquidity) to proxy for liquidity constraints and mortgage-to-housing-value (Leverage) to proxy for LTV constraints. Low liquid assets imply the household is hardly saving except through mortgage payments, which makes this household more likely to be financially constrained (Gross and Souleles, 2002). The coefficient on $Exposure \times Liquidity$ in column (2) of Table 3 is not statistically different

Table 3: Post-Reform Heterogeneity Depending on Credit Constraints

	Benchmark (1)	Liquidity (2)	Leverage (3)	Young (4)	HP Growth (5)
Exposure	0.055***	0.057***	0.060***	0.049***	0.050***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)
Exposure×Z_i		-0.005	-0.012**	0.016***	
		(0.004)	(0.004)	(0.004)	
Exposure×HP Growth quartile 2					-0.003
					(0.007)
Exposure×HP Growth quartile 3					0.006
					(0.007)
Exposure×HP Growth quartile 4					0.020**
					(0.007)
Observations	1,514,460	1,514,460	1,514,460	1,514,460	1,514,460

Notes: The table presents estimates of the post-reform (2004-2010) period effect of Exposure on consumption growth, where Exposure is normalized to zero mean and unit variance. The results are from the following regression:

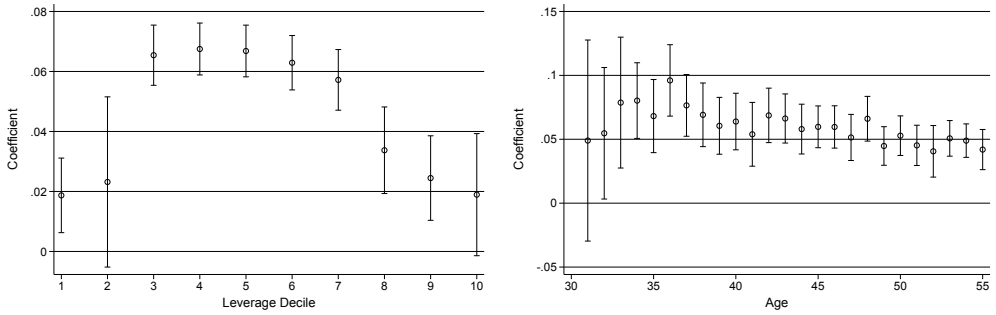
$$\frac{Consumption_{i,\tau \to T}}{Consumption_{i,2000}} = \alpha + \beta_1 Exposure_i \times \tau + \beta_2 Exposure_i \times Z_i \times \tau + \gamma X_i + \delta_\tau + \epsilon_{i,\tau},$$

where the dependent variable is Consumption expenditure normalized by its 2000 value. We include age dummies, family size dummies, education level, and municipality dummies, a dummy for liquidity constrained in 2002, leverage dummy in 2002, and house-price growth quartile dummies. House-price growth is calculated as the increase in square meter prices from 2002 to 2006. *, **, *** denote statistical significance at the 5%, 1% and 0.1% level. Standard errors clustered on municipality in parentheses.

from zero. In column (3), we find a higher leverage predicts a *lower* response. Figure 6(a) shows this relationship follows an inverse U-shape. In the figure we divide the sample into 10 groups based on 2002 leverage, and plot the coefficient on the interaction between leverage and exposure. As the figure shows, the coefficient on exposure for the groups with the lowest and highest leverage is small. For households in the middle, the coefficient on leverage is noticeably larger. This pattern is consistent with tighter borrowing constraints for highly levered households, who are not able to take advantage of the reduction in payments. The conceptual framework predicts the borrower is unable to increase consumption from the lower payment on the IO loan if the LTV constraint is binding (consumption could increase because of lower amortization payment, however). Consistent with binding LTV constraint to limit the response to lower amortization payments (see Bhutta and Keys, 2016), the increase in consumption is smaller for households with higher leverage.

In column (4) of Table 3, we show the impact of exposure on consump-

Figure 6: Heterogeneity in Results by Age and Leverage



(a) Leverage deciles

(b) Age in 2002

Notes: The figures presents estimates of the post reform (2004-2010) period effect of Exposure on consumption growth for (a) the leverage deciles, and (b) householder age, where Exposure is normalized to zero mean and unit variance. The dependent variable is Consumption expenditure normalized by its 2000 value. In all specifications we include age dummies, family size dummies, education level, municipality dummies. Standard errors clustered on municipality in parentheses. 95 percent confidence intervals.

tion is larger for households younger than 45 in 2002. Figure 6(b) shows this relationship is approximately linear. Larsen et al. (2018) similarly show that young households use IO mortgages to increase consumption, whereas households above 45 use them to increase pension savings and investments.

In column (5) of Table 3 we provide results depending on house-price growth during the boom. We divide municipalities into four groups according to the house-price growth, and estimate the results for Exposure for each house-price growth quartile. The impact of exposure is larger in areas with the highest house-price growth, but is still positive and significant even in areas with low house price growth.

5.3 Aggregate Estimates

Following Berger et al. (2016) and Mian and Sufi (2012), we compute the aggregate impact of interest-only mortgages on consumption by exploiting cross-sectional differences in exposure. We choose the bottom one percent of exposure as the control group, and compute the impact of the reform relative to this group. Standardized exposure is -1.64 for the bottom group, increasing to 6.9 for the top group. For each group g, the aggregate increase

in consumption due to IO mortgages is equal to:

$$\Delta Consumption_g = \beta \times (e_g - (-0.65)) \times Consumption_{g,2002}, \qquad (4)$$

where β is the coefficient on post-reform in column (1) of Table 3 for the full post-reform period, e_g is standardized exposure of group g, and $Consumption_{g,2002}$ is the consumption expenditure for group g in 2002. We calculate the aggregate impact of IO mortgages on consumption expenditure by summing across all groups. The total increase in consumption expenditure for our sample over the post-reform period is 14.7 percent. Provided that the bottom group is a legitimate control group, we estimate the introduction of interest-only mortgages increased consumption expenditure by 8.2 percent between 2003 and 2010, corresponding to 52 percent of the total increase in consumption.

5.4 Discussion of Aggregate Level Results

Our results show households who are more likely to take out an interest-only have a higher consumption growth than households who are less likely to do so. In essence, our empirical strategy uses the group with the lowest exposure as the counterfactual, meaning we assume that this group does not benefit from the reform. In the conceptual framework, this assumption derives from the collateral constraint, where households with low exposure are being constrained by the LTV constraint and thus do not benefit from lower mortgage payments. Although Figure 6(a) shows that households with high leverage do not respond strongly to the reform, valid reasons exists for discussing the assumption. Indeed ,households with low exposure also use IO mortgages and their consumption may well increase due to lower savings.

In particular, an important consideration is the general equilibrium effect of the reform, particularly with regards to the dramatic increase in house prices that followed the introduction of interest-only mortgages (Bäckman and Lutz, 2018). Even if IO mortgages are only valuable for payment-constrained borrowers, these borrowers could use the increase in borrowing to bid up prices. This would lead to higher collateral values, which in turn would affect the ability of households facing leverage con-

straints to borrow. With higher collateral values, even households with low exposure would benefit and could increase their consumption. This implies that our control group are also positively affected by the reform, which impact our results to the extent that the control groups benefits more from higher collateral values. Importantly, this implies that we *underestimate* the effects of the reform, as the control group is also positively affected.

Note also that at least a share of initially PTI-constrained households benefit from an increase in collateral values. When the PTI constraint becomes looser, some households switch from being constrained by payments to being constrained by collateral.

These effects are a part of the impact of introducing interest-only mortgages. If borrowing is constrained by payments, the increase in borrowing will not only affect consumption, but also housing markets. If housing supply is inelastic, an increase in demand leads to an increase in house prices. Fundamentally, it is difficult to imagine a situation where the payment constraint is changed only for existing borrowers, and where house prices remain the same. Higher house prices is a part of the mechanism that causes higher consumption.

If house prices increase for a different reason, perhaps due to house-price expectations, then housing-wealth effects represents another threat to our empirical design. However, previous studies using Danish data have also not found large housing wealth effects (Browning et al., 2013), or have found that wealth effects are driven by the incentive to refinance (Andersen and Leth-Petersen, 2019). Moreover, given the municipality fixed effects in our empirical design, households with higher exposure *within a municipality* would have to benefit more from higher house prices. The previous results instead suggest that households with high exposure should have a *lower* marginal propensity to consume out of housing wealth compared to households with low exposure: it is the households with lower leverage who are driving the results. This contrasts the empirical evidence on housing wealth effects, who typically find that more levered households have a higher MPC out of housing wealth (Mian et al., 2013, see, e.g.,).

Finally, if house-price shocks are driving the results, we would expect a *decline* in consumption in the late post-reform period (2007-2010), as house prices decreased dramatically during this period (see e.g. Mian et al., 2013).

The year-by-year results in Figure 5 do not support this hypothesis.

6 Borrowing Level and Savings Rate after Refinancing to an Interest-Only Mortgage

The previous results show consumption increased more for households exposed to interest-only mortgages. In this section, we employ a different identification strategy that exploits the timing of mortgage refinancing together with the household fixed effects to estimate how consumption is affected by refinancing. This exercise allows for disentangling the growth in consumption expenditure into two parts. First, a spike in consumption-to-income at the time of refinancing indicates an increase in borrowing for consumption purposes at the time a household chooses an interest-only mortgage. Second, a lower savings rate will be reflected in a higher consumption-to-income ratio after the initial borrowing period.

Estimating dynamic effects can be challenging for several reasons. Households who choose an interest-only mortgage may differ from the rest of the population in ways that affect their consumption expenditure. For instance, Andersen et al. (2019) show Danish households differ in their propensity to refinance. Although we control for fixed characteristics, time-varying characteristics correlated with choosing an interest-only mortgage provide a challenge, because households may respond differently to time-varying incentives to refinance. To address this concern, we select a sample of households who refinance to an interest-only mortgage, and exploit the difference in timing across refinancing events. A similar strategy is employed by Druedahl and Martinello (2018) to study the effect of inheritances on long-run wealth accumulation and by Fadlon and Nielsen (2015) to study the effect of health shocks on household labor supply.

The difference-in-differences approach is illustrated in Figure 7. Consumption-to-income ratios are similar up to 2004, start to differ in the year prior to refinancing, spike in the year of refinancing, and converge to a similar level after refinancing. We can eliminate year and group fixed effects by using the variation in the figure, but doing so limits us to the information available for those two years. To implement the same strategy for all years, we

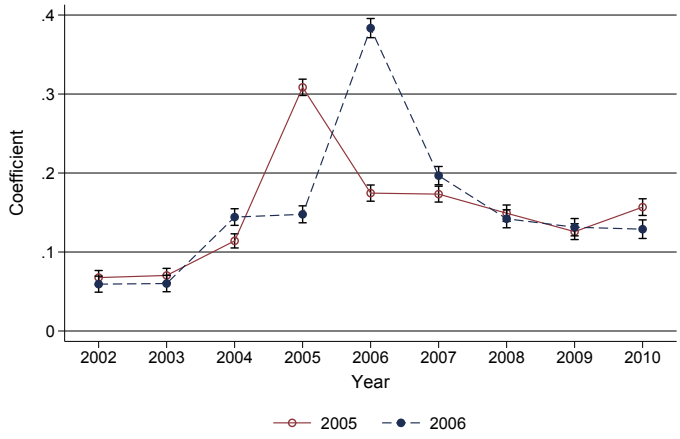


Figure 7: Example of Identification Strategy

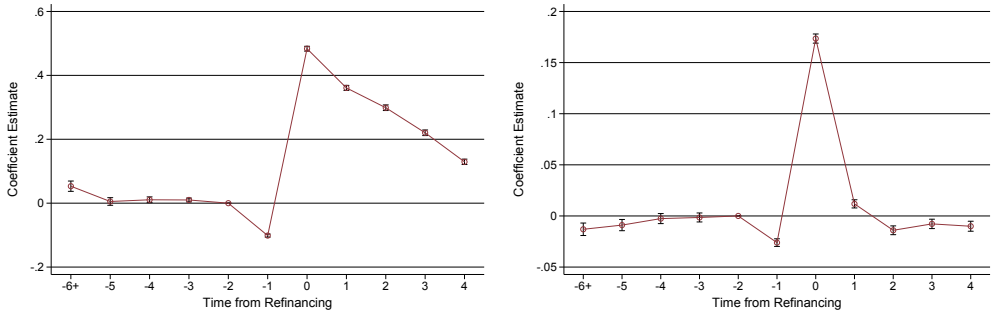
Note: The figure shows the estimated effects and 95 percent confidence intervals of refinancing to an IO mortgage on consumption to disposable income in 2005 and 2006. The plotted coefficients are year dummies. Standard errors are clustered on the individual borrower level.

follow Druedahl and Martinello (2018) and describe the consumption-to-disposable-income ratio C/Y at year t of a household i refinancing at time τ_i as:

$$\frac{C_{i,t}}{Y_{i,t}} = \gamma_{<-3}\mathbf{1}[t-\tau_i<-3] \quad + \quad \sum_{n=-5}^{-2}\gamma_n^{pre}\mathbf{1}[t-\tau_i=n] \\ + \quad \sum_{n=0}^{6}\gamma_n^{post}\mathbf{1}[t-\tau_i=n] + \alpha_t + \psi_i + \epsilon_{i,t}, \quad (5)$$

where α_t and ψ_i are year and household fixed effects, respectively. We repeat the procedure for mortgage-debt-to-income and total-assets-to-income. For any observation prior to three years before refinancing, $\gamma_{<-3}$ is a normalization. The reference category for γ^{pre} and γ^{post} is two years before refinancing. All regression estimations are clustered at the household level. Druedahl and Martinello (2018) show this approach can be viewed as an event study with separately identifiable year and year-by-cohort fixed effects. The approach maintains the identification assumption of a common difference-in-difference, but allows us to use all available information in the same estimation to identify the effect of choosing an IO mortgage beyond the point where the second group chooses an IO mortgage.

Figure 8: Dynamics of Consumption and Mortgage Debt



(a) Mortgage Debt to Disposable Income

(b) Consumption to Disposable Income

Notes: The figures shows the estimated effects and 95 percent confidence intervals of refinancing to an IO mortgage on (a) mortgage to disposable income and (b) consumption to disposable income. The effects are estimated before and after refinancing to an IO mortgage according to equation 5. Standard errors are clustered on the individual borrower level.

We present results in Figure 8 and Table 5. Figure 8(a) shows the mortgage-debt-to-income ratio spikes in the year of refinancing. Relative to the average, the ratio increases by 19 percent at the time of refinancing and remains elevated in the years after refinancing. The increase in mortgage debt in the same period translates into a large impact on consumption expenditure – the consumption-to-disposable-income ratio increases by 15 percent at the time of refinancing. Together, these quantities imply that about three quarters of the mortgage debt goes into consumption expenditure.

Notably, we do not find that consumption expenditure is higher after refinancing to an IO mortgage. Together with the result that consumption spikes in the year of refinancing, the impact on consumption from IO mortgages is driven by a one-time increase in consumption at the time of refinancing. Although this finding is somewhat surprising, it is consistent with IO mortgages relaxing financial constraints related to mortgage payments at the time of refinancing for the individuals who chose an IO mortgage. Because we are examining within-household differences in consumption over time, these results suggest borrowing constraints were loosened but consumption continued on a path similar to pre-refinancing levels.

Our analysis focuses on the average response to IO mortgages. How-

ever, the response may differ across households with a different need for consumption smoothing. We therefore analyze heterogeneity in the response to choosing an IO mortgage across several empirical measures of credit constraints and the need for consumption smoothing.

Table 6 provides the results for mortgage-to-income, consumption-to-income and assets-to-income as the dependent variable. We use several proxies for credit constraints. First, we use the house-value-to-income ratio to measure the importance of payment-to-income constraint. We have interacted a dummy for high house-value-to-income ratio with the time period of our focus. Specifically, house-value-to-income in this table is a dummy equal to one if house-value-to-income in 2002 is above the median. We interact time dummies with the group indicator, and report a coefficient on a dummy for a pre-refinancing period equal to one if refinancing is more than two years in the future, a coefficient for the year of refinancing, and a coefficient for the post-refinancing period.

Households with a above median house-value-to-income ratio increase their mortgage-to-income by more than households with a below-median house-value-to-income ratio, and their consumption response in the year of refinancing is also higher. Households with an above-median house-value-to-income increase their mortgage by 0.73 times disposable income, compared to 0.44 times disposable income for below-median households. Moreover, above-median households have a significantly larger post-refinancing consumption level, which suggests a household with a high house-value-to-income ratio has a larger marginal propensity to consume out of amortization payments.

Second, younger households (< 45 years old) borrow significantly smaller amounts during refinancing to an IO mortgage, which translates to a significantly lower impact on consumption. Young households also have a lower consumption-to-disposable-income ratio in the years after refinancing than older households. Older households therefore, on average, use IO mortgages to reduce savings.

Third, liquidity- and borrowing-constrained households increase their mortgage by less, and consume less in the year of refinancing. Consistent with the theoretical framework, an IO mortgage leads to a lower increase in mortgage debt and in consumption for borrowing-constrained households,

defined as having a high loan-to-value ratio in 2002.

Taken together, our findings suggest an important heterogeneity in the responses across households. Households with higher house-value-to-income ratios are able to borrow more with an IO mortgage, and also increase their consumption more. However, with a binding collateral constraint, the benefit from an IO mortgage is lower. These results are broadly consistent with IO mortgages relaxing PTI constraints.

7 Conclusion

We examine the impact of interest-only mortgages on consumption growth. Using a measure of exposure to the mortgage reform observed prior to the introduction of the new mortgage product, we find the introduction of IO mortgages had a positive and significant impact on household consumption and borrowing. In aggregate, the IO-mortgage reform explains approximately half of the growth in consumption expenditure between 2003 and 2010. Moreover, we find that this result is primarily driven by higher borrowing at the time of refinancing rather than lower amortization payments.

Overall, our results show that *changing* amortization payments can have a large impact on consumption expenditure. If a large number of households choose to refinance over the same period, the one-time adjustment in mortgages can have a substantial impact on the growth rate of aggregate consumption. Both additional borrowing and the lower amortization rate will lead to a higher level of consumption, but the aggregate effect may dissipate as more and more households have already refinanced. Our findings suggest the presence of interest-only mortgages as a mortgage option may turn out to be not substantial in affecting aggregate consumption dynamics after the initial shock to consumption has expired. However, the introduction and the increased popularity of these mortgages create the increase in consumption in Denmark rather than the availability of these mortgages.

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For Online Publication: Appendices

A Appendix: Municipality-Level Price Index

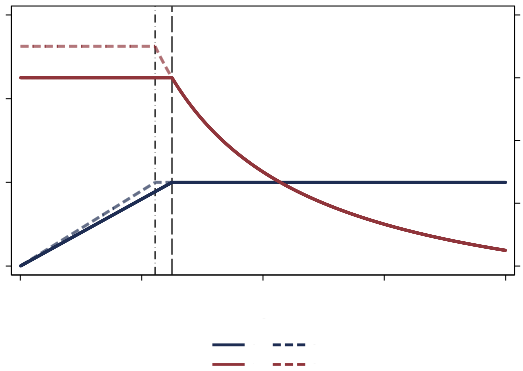
We construct a municipality level house price index using data on all transactions in Denmark. The data is from The Danish Gazette (*Statstidende*), and covers the universe of Danish property transactions as a part of the judicial process of transferring ownership. We combine the data on property sales with data on individual property characteristics from the Housing Register (*Bygnings- og Boligregister*, BBR). Further, we collect data on property ownership to identify trades between spouses and family members, and to identify trades that occur due to the death of a spouse or due to divorce. These trades are removed from the final sample, as they are less likely to be sold at market prices.[22]

After collecting the data on all property transactions, we connect each house and apartment to the Housing Register (BBR) to find the property type (apartment, single-family house or summer house). We further drop outliers in the sales price by removing the top and bottom 1 percent in the sales price distribution, and by removing any transactions where the transaction price is listed as zero. The resulting sample of households are then used to calculate the average square meter price for traded properties in all municipalities.

[22]Removing family trades and similar non-market transactions are common in the construction of real estate indices. See, e.g., the S&P Case-Shiller index methodology: http://us.spindices.com/index-family/real-estate/sp-case-shiller.

B Appendix: Figures

Figure 9: Borrowing under Two Constraints



Notes: The figure plots maximum borrowing when we increase the LTV ratio from 0.8 to 0.9. All parameter values are the same as in Figure 2, unless otherwise indicated. The solid blue (red) is the maximum borrowing (leverage) under the LTV and PTI constraint. The dashed blue (red) line is the maximum borrowing (leverage) under the new LTV ratio.

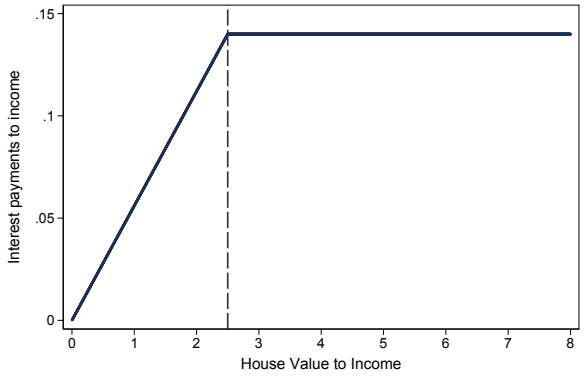


Figure 10: Interest payment to income relative to house value to income

Notes: The figure plots interest payment to income against house value to income. All parameter values are the same as in Figure 2, unless otherwise indicated. Interest payments are calculated as the mortgage debt to income times the mortgage rate. The dashed vertical line shows the threshold where the payment-to-income constraint starts to bind.

C Appendix: Tables

Table 4: Summary Statistics

	Low HV/Inc	Mid HV/Inc	High HV/Inc	Difference Highest-Lowest
Housing Market Characteristics				
House Price Growth 2003-2006	28.39	35.48	45.92	-17.54***
	(12.46)	(13.90)	(14.33)	[-211.73]
Household Demographic Characteristics				
Age	45.54	45.78	46.69	-1.15***
	(6.49)	(6.39)	(6.33)	[-28.98]
Education Length	14.18	14.41	14.49	-0.31***
	(2.21)	(2.07)	(2.28)	[-22.21]
Family Size	3.22	3.18	2.78	0.44***
	(1.21)	(1.19)	(1.33)	[55.47]
Employment Ratio during the Year	0.97	0.98	0.97	0.00***
	(0.08)	(0.08)	(0.10)	[4.04]
Household Financial Characteristics				
Consumption	362,535	370,530	363,718	-1,183
	(145,678)	(152,520)	(184,820)	[-1]
Disposable Income	367,609	368,001	347,741	19,868***
	(177,990)	(105,393)	(128,693)	[21]
Mortgage Debt	447,310	633,561	771,091	-323,781***
	(317,720)	(372,859)	(523,486)	[-121]
House Value	813,093	1,234,971	1,800,124	-987,031***
	(306,925)	(376,817)	(754,621)	[-278]
Housing Wealth to Income	2	3	5	-3***
	(0)	(0)	(2)	[-397]
Sum of Liquid Assets	141,065	134,738	169,312	-28,247**
	(661,930)	(303,001)	(1,900,740)	[-3]
Interest Payments	42,303	52,643	55,771	-13,468***
	(25,850)	(28,270)	(35,579)	[-70]
Consumption growth 2002-2006	0.08	0.11	0.14	-0.06***
	(0.46)	(0.47)	(0.54)	[-19.58]
Income growth 2002-2006	0.03	0.04	0.05	-0.02***
	(0.17)	(0.16)	(0.22)	[-15.11]
IO mortgage	0.30	0.38	0.49	-0.19***
	(0.46)	(0.49)	(0.50)	[-52.47]
Liquid Assets to Income	0.34	0.35	0.46	-0.12***
	(0.62)	(0.61)	(0.81)	[-26.77]
Mortgage to Income	1.23	1.74	2.26	-1.03***
	(0.80)	(0.92)	(1.36)	[-149.47]
Equity Extraction	0.14	0.16	0.19	-0.05***
	(0.35)	(0.37)	(0.39)	[-21.00]
Mortgage Rate	0.07	0.07	0.07	0.00***
	(0.05)	(0.04)	(0.04)	[15.10]
Interest Payments to Income	0.08	0.10	0.12	-0.03***
	(0.05)	(0.05)	(0.07)	[-96.32]
Liquidity Constrained	0.45	0.43	0.37	0.08***
	(0.50)	(0.49)	(0.48)	[26.33]
Borrowing Constrained	0.61	0.62	0.51	0.11***
	(0.49)	(0.49)	(0.50)	[35.64]
Observations	52568	52568	52567	105135

Notes:
Table reports summary statistics for households over groups of house-value-to-income ratio, and the differences between them, including the results from a T-test for the differences. We report demographic and financial characteristics. Demographics include age, years of education, family size and the employment ratio during the year. Financial characteristics include consumption (defined in section 3), disposable income (the sum of income minus taxes, transfers and interest-payments), mortgage debt as the market value of outstanding mortgage debt, house value as the tax assessed value of all housing properties multiplied by the scaling factor, liquid assets as the sum of stocks, bonds and cash deposits holdings, interest payments as the sum of mortgage and bank deb interest payments. Mortgage rate is the sum of mortgage interest payments divided by the market value of the mortgage. All variables marked as "to Income" are divided by disposable income. House price growth is defined as the percentage growth in square meter prices from 2003 to 2006. Personal income growth is the percentage growth in personal income (defined as the total income that the individual receives from all sources). Equity extraction is a dummy equal to one if mortgage debt increases by more than 10 percent year-over-year. IO mortgage is a dummy equal to one if the individual holds an IO mortgage in 2009. Liquidity constrained is a dummy equal to one if liquid assets are less than 1.5 months of income, and borrowing constrained is a dummy equal to one if mortgage value divided by house value is greater than 0.5. Standard deviations are in parentheses. ***, **, * denote significance at the 1%, 5%, and 10% for the T-test.

Table 5: Difference in Difference Results

	(1) Mortgage	(2) Consumption	(3) Assets
-6+	0.017***	-0.018***	0.061***
	(0.004)	(0.003)	(0.014)
-5	-0.000	-0.011***	0.055***
	(0.003)	(0.003)	(0.011)
-4	0.004*	-0.004	0.043***
	(0.002)	(0.002)	(0.009)
-3	0.005***	-0.003	0.040***
	(0.001)	(0.002)	(0.007)
-1	-0.044***	-0.023***	-0.184***
	(0.001)	(0.002)	(0.006)
0	0.194***	0.152***	0.439***
	(0.002)	(0.002)	(0.007)
1	0.149***	0.001	0.065***
	(0.002)	(0.002)	(0.007)
2	0.125***	-0.020***	0.007
	(0.002)	(0.002)	(0.008)
3	0.095***	-0.013***	-0.015
	(0.002)	(0.003)	(0.009)
4	0.062***	-0.012***	-0.021*
	(0.002)	(0.003)	(0.009)
Observations	438,142	435,062	440,515

Notes: The table shows the estimated effects and standard errors from estimating equation 5. Control variables include age dummies, education length and family size. All regressions include household fixed effects and year dummies. *, **, *** denote statistical significance at the 5%, 1% and 0.1% level. Standard errors clustered on households in parentheses.

Table 6: Heterogeneity in Dynamics – Age and House Value to Income

	Mortgage to income (1)	Consumption to income (2)	Assets to income (3)	Mortgage to income (4)	Consumption to income (5)	Assets to income (6)
	X = House Value to Income			X = Age		
Pre Refinancing	-0.118***	0.003	0.034***	-0.041***	0.013***	-0.001
	(0.005)	(0.002)	(0.002)	(0.005)	(0.002)	(0.003)
Year of Refinancing	0.440***	0.171***	0.123***	0.657***	0.207***	0.222***
	(0.005)	(0.003)	(0.003)	(0.006)	(0.003)	(0.004)
Post Refinancing	0.328***	0.006**	0.036***	0.557***	0.019***	0.120***
	(0.006)	(0.002)	(0.003)	(0.007)	(0.002)	(0.004)
Pre Refinancing × X	0.117***	0.005**	-0.025***	-0.033***	-0.016***	0.045***
	(0.005)	(0.002)	(0.003)	(0.007)	(0.003)	(0.003)
Year of Refinancing × X	0.290***	0.029***	0.105***	-0.103***	-0.043***	-0.081***
	(0.007)	(0.004)	(0.004)	(0.008)	(0.004)	(0.005)
Post Refinancing × X	0.256***	0.008***	0.039***	-0.160***	-0.017***	-0.121***
	(0.005)	(0.002)	(0.003)	(0.009)	(0.003)	(0.004)
	X = Liquidity Constrained			X = Borrowing Constrained		
Pre Refinancing	-0.012*	0.009***	0.023***	-0.131***	-0.014***	-0.023***
	(0.005)	(0.002)	(0.003)	(0.008)	(0.003)	(0.005)
Year of Refinancing	0.638***	0.206***	0.229***	0.884***	0.273***	0.310***
	(0.006)	(0.003)	(0.004)	(0.010)	(0.005)	(0.006)
Post Refinancing	0.493***	0.019***	0.104***	0.796***	0.044***	0.207***
	(0.008)	(0.003)	(0.004)	(0.012)	(0.003)	(0.007)
Pre Refinancing × X	-0.080***	-0.005	-0.004	0.093***	0.025***	0.055***
	(0.007)	(0.003)	(0.003)	(0.008)	(0.003)	(0.005)
Year of Refinancing × X	-0.054***	-0.036***	-0.083***	-0.349***	-0.108***	-0.160***
	(0.008)	(0.004)	(0.005)	(0.011)	(0.006)	(0.007)
Post Refinancing × X	-0.024**	-0.015***	-0.074***	-0.398***	-0.042***	-0.181***
	(0.009)	(0.003)	(0.005)	(0.012)	(0.003)	(0.007)
Observations	443,183	429,343	444,427	443,183	429,343	444,427

Notes: The table shows the estimated effects and standard errors from estimating equation 5 with interactions. The interaction variable is listed in the top row (X = House Value to Income for interaction effects by a dummy for above median house value to income). House value to income is a dummy equal to one for values above the median value in 2002. Young is a dummy equal to one if the individual is below 45 years of age. Liquidity constrained is a dummy equal to one if the sum of liquid assets is less than 1.5 months of disposable income. Borrowing constrained is a dummy equal to one if mortgage values in 2002 was above 0.5 times house values. Control variables include age dummies, education length and family size. All regressions include individual fixed effects and year dummies. *, **, *** denote statistical significance at the 5%, 1% and 0.1% level. Standard errors clustered on individuals in parentheses.