Financial Innovation and Consumption

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Abstract

We use detailed household-level data from Denmark to show that the introduction of interest-only mortgages allowed households constrained by their mortgage payments to increase consumption and borrowing. Using an ex-ante measure of exposure motivated by theories of financial constraints, we show that households with higher exposure were more likely to refinance to an IO mortgage and that they increased their consumption more following the reform. We find that interest-only mortgages are popular across the income and age distribution, suggesting that this type of financial innovation affects a large share of the population. Finally, we show that the increased prevalence of interest-only mortgage have important implications for the estimation of housing wealth effects.

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1 Introduction

In the United States unconventional mortgage products accounted for approximately 50 percent of mortgage origination in 2007, having increased from one percent in 2000 (Justiniano et al., 2017). These products are often structured to allow households to reduce amortization payments early in the loan, allowing for lower savings rates and potentially more borrowing as a result of the lower initial monthly payments (Cocco, 2013). Given the prominence of these products in the housing boom and their prevalence in different parts of the income distribution as compared to subprime mortgages (Amromin et al., Forthcoming), the role of interest-only mortgages and similar unconventional products for borrowing and savings decisions has been surprisingly limited.

In this paper we explore how household consumption respond to new mortgage products by studying the legalization of interest-only mortgages in Denmark. This new product was introduced in 2003 into an otherwise traditional mortgage market, allowing households to postpone amortization payments for up to 10 years. This new product rapidly becoming the preferred mortgage choice for a large share of the population, reaching 50 percent of outstanding mortgage debt only three years after their introduction. We find that many households used these products to increase their consumption and their borrowing. Figure 1 plots consumption growth for households that are observed to hold an IO mortgage in 2009, showing that households that chose such a mortgage product rapidly increased their consumption after the reform in 2003. This higher consumption level remained even as the housing market cycle turned down in 2007. In the graph the highest consumption growth is observed for the group with the highest ex-ante benefit of choosing an IO mortgage, the group defined as Exposed.

We argue that this is consistent with loosening of financial constraints related to mortgage payments. These types of constraints are likely to affect a large share of the population, who could increase their utility by choosing an interest-only mortgage. For example, Gorea and Midrigan (2017) estimate that 70 percent of US households are liquid-
Figure 1: Consumption Growth for IO Mortgage Holders

*Notes:* Consumption growth across groups. Households who are observed holding an IO mortgage in 2009, the earliest year when we have data are in red, whereas households not holding an IO mortgage are in blue. Exposed and Unexposed measure the benefit of the reform, defined as having an above median housing-wealth to income ratio. Consumption is normalized to 1 in 2000 for all groups.

ity constrained, and Piskorski and Tchistyj (2010) argue that an interest-only mortgage with an attached credit line is the optimal mortgage product. However, these households are not primarily attractive low income or low-quality borrowers, and are instead used by a large fraction of both high and low income households. Indeed, we show that the IO mortgage share ranges from just below 70 percent for low income households to 60 percent for high income households. This corresponds to statistics reported in Amromin et al. (Forthcoming), who show that the share of “complex” mortgages was increasing in income, house values and credit scores.

In particular, we show in a simple theoretical framework that these mortgages are valuable for borrowers facing borrowing constraints related to their mortgage payments, but not to households facing leverage constraints. Our framework incorporates two types of financial constraints (see Gorea and Midrigan, 2017; Greenwald, 2017; Grodecka, 2017, for more detailed models of these two constraints). We argue that lower amortization payments affect households facing a Payment-to-Income (PTI) constraint, but not those facing the traditional Loan-to-Value (LTV) constraint. The key question then becomes
whether the LTV or PTI constraint is binding, as relaxing a slack constraint does not impact borrowing. We show that a simple formula captures the importance of PTI constraints relative to the LTV constraints: a higher housing wealth to income ratio implies that it is more likely that it is the payments on the mortgage that limits borrowing, not the value of the collateral. Furthermore, we show that this simple formula strongly predicts IO loan use among households. Figure 8 plots the IO mortgage share against housing wealth to income using individual-level data, showing a strongly increasing relationship between the two variables.\footnote{Amromin et al. (Forthcoming) show the same pattern for the United States.}

![Graph showing Housing Wealth to Income and IO Loans](image)

Figure 2: Housing Wealth to Income and IO Loans

*Notes: Binscatter plot of housing wealth to income ratios against the IO mortgage share in 2009. Plot is constructed with 100 bins.*

We use the intuition developed in the theoretical framework to estimate the impact of IO mortgages on consumption expenditure. Our empirical strategy compares households with different benefits from choosing an IO mortgage. Specifically, we measure the benefit (exposure) to the reform by ranking households based on their housing wealth to income ratios in 2002. Households with low exposure acts as a control group, and we compare their outcomes to households with high exposure. This strategy avoids comparing households who refinance to an IO mortgage to households who do not refinance,
which is important because that is a choice that may be correlated with several other unobservable factors.

We present two main findings. First, IO mortgages had a strong impact on consumption expenditure over the course of the housing market cycle. Importantly, the impact remains positive and significant over the housing market boom and bust, which suggests that the results are not driven by housing wealth effects or higher income expectations. The results are not driven by higher income growth, housing wealth effects or municipality-specific labor market developments. Second, because IO mortgage affects consumption expenditure for households in areas with high house price growth, there is an upwards bias in the estimated housing wealth effects from cross-sectional regressions. Instruments based on housing supply do not alleviate this concern, as housing supply creates differences in price levels across locations that precisely capture the importance of PTI constraints.

The main threat to identification is time-varying shocks correlated with exposure, such as housing wealth effects or differential trends in income growth. We address these concerns in five ways. First, analysis of time-trends indicate parallel trends in consumption growth prior to the reform across groups with differing levels of exposure to the reform, followed by a clear break with increasing consumption growth for groups with high exposure and continued higher consumption growth. This results holds even as the housing market cycle turns and house prices decline by an average of 30 percent. This indicates that it is indeed IO mortgages driving consumption growth, and not time-varying factors such as higher income growth over the business cycle or differences in expectations. Second, all estimates are robust to including municipality-year fixed effects to control for income and house price growth for a small locality. Third, we examine the components of consumption and show that consumption growth is primarily driven by the factors affected by IO mortgages. In particular, we find higher debt levels and higher disposable income driven by lower interest rates, but no differences in trends in income growth in general. The lack of a difference in income growth is particularly important.
because it reduces concerns that consumption differences across groups was driven by different labor market outcomes over the business cycle.

Fourth, we show that housing wealth effects are negligible and indeed not statistically significant in any other period. Browning et al. (2013) rule out housing wealth effects from 1987-1996, and we extend their results up until 2010. We find no evidence of a housing wealth effect except for the period between 2004 and 2006. This results holds for any subgroup of the population that we consider, including liquidity constraints, borrowing constraints and across age groups. The conclusion is that it is not likely that our results are driven by housing wealth effects. Fifth, we estimate that the effect of IO mortgages is similar across municipalities that experienced low and high house price growth. Together with the result that housing wealth effects are small, our conclusion is that IO mortgages act as a “common factor” for house prices and consumption (Pagano, 1990; Attanasio et al., 2009).

The Danish institutional framework for mortgage financing helps rule out several confounding factors. Bäckman and Lutz (2016) conduct an analysis of credit supply shifts in Denmark during this time period, and find no support for lowered lending standards or shifts towards riskier borrowing. 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. For example, households were limited to an 80 percent loan to value ratio and were evaluated on their ability to afford higher interest payments. In addition, borrowers have a strong incentive to conform to these limits and to not overextend themselves because of recourse laws. All debt in Denmark is full recourse, allowing mortgage banks to both repossess collateral and garnish incomes until the outstanding debt is repaid in the case of a household default. These laws are enforced. All the above
implies that mortgage debt is more strictly regulated and is riskier for borrowers in Denmark compared to the United States, with corresponding incentives for both mortgage banks and households to not unduly speculate on rising house prices. Brueckner et al. (2016) argue that because IO mortgage 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 institutional framework limits this concern, although we are not able to fully rule it out.

Our paper contributes to the literature on the causes of the financial crisis by providing a new explanation for the rise in mortgage debt across the income distribution (Adelino et al., 2016; Foote et al., 2016; Albanesi et al., 2017). Since IO mortgages are popular across the income distribution, our results suggest that financial innovation can induce more borrowing not only for subprime or low-income borrower, but also for high-income households. This is not only a relevant fact for Denmark, but also corresponds to evidence from the United States, where Amromin et al. (Forthcoming) show that interest-only mortgages and other similar products were a popular choice also for prime borrowers.\(^2\) We show that IO mortgages were a popular choice across the income distribution, and that they later also affected their borrowing.

Our results also provide new evidence on the effect of lower mortgage payments for consumption and borrowing. Di Maggio et al. (2017) find that lower mortgage payment substantially increase consumption, especially for households with high loan-to-value ratios. Cloyne et al. (2016) show that borrowers in the United Kingdom and the United States increase their spending in response to lower interest payments. Bhutta and Keys (2016) find that interest payments have a substantial impact on household borrowing, and that the effect is particularly pronounced among younger borrowers with prime credit scores. As the authors discuss, it is possible that their results reflect relaxed payment to income constraints. Our theoretical framework provides some intuition for thinking about the effect of lower payments on consumption, and our empirical findings suggest

\(^2\)In the United States interest-only mortgages also became increasingly prevalent over the course of the housing boom (Barlevy and Fisher, 2012; Brueckner et al., 2016).
that amortization payments are an important tool for lower mortgage payments among households facing PTI constraints. This is important especially important for regulators, who are increasingly using macro-prudential tools such as debt-service-to-income ratios or higher amortization payments to reduce macroeconomic risk and household indebtedness (Kuttner and Shim, 2016). One proposed tools, higher amortization payments, can according to our results also impact borrowing and consumption expenditure.

Finally, our results have important implications for the estimation of housing wealth effects. Causal identification of housing wealth effect often relies on cross-sectional variation in house price growth and consumption, combined with an instrument based on housing supply (e.g. Mian and Sufi, 2011; Aladangady, 2017; Mian et al., 2013). The theoretical motivation is derived from Glaeser et al. (2008), who show that for an equivalent housing demand shock the supply curve determines the price response. The identifying assumption behind using housing supply as an instrument for house price growth is therefore that the demand shock is similar across locations.\textsuperscript{3} However, our theoretical framework shows that lower amortization payments or indeed lower interest rates affect households differently depending on the housing wealth to income ratio. This ratio is correlated with supply constraints, which implies that the demand shock for an equivalent shock to interest rates differs across locations with different housing supply levels. The result of the introduction of IO mortgages was an increase in consumption expenditure, which occurs in the same areas where house price growth was high. Observationally, we therefore have that consumption increases in the areas where house price growth was high because of IO loans, threatening causal identification of housing wealth effects based on cross-sectional variation in house prices.

Section 2 provides a conceptual framework for how IO mortgages affect consumption for borrowing constrained households. Section 3 gives an overview of the Danish mortgage market and the introduction of interest-only mortgages. Section 4 describes the data, the sample selection and the empirical strategy. Section 5 presents the results, Section 6

\textsuperscript{3}See Davidoff et al. (2016) for another criticism of the instrument.
provides evidence on alternative channels, and Section 7 concludes.

2 Conceptual Framework

In this section we discuss a framework for analyzing how the introduction of interest-only mortgage affect consumption among existing homeowners. We focus on two different constraints and argue that IO mortgages affect households constrained by the payments on their mortgage, not those constrained by the value of their collateral.\(^4\) Specifically, we use insights from life-cycle models where households choose their savings based on their permanent income to achieve a smooth level of consumption across the life-cycle (Friedman, 1957; Carroll, 1997; Gourincas and Parker, 2002). We argue that IO mortgages only affect the consumption of households who are constrained, i.e. households who are not able to fully smooth consumption across the life-cycle. Furthermore, we argue that only household constrained by mortgage payments are affected by IO mortgages, as this is the type of constraint affected by the lower amortization payments afforded by an IO mortgage.

With perfect credit markets desired consumption equals actual consumption, and in case current income is lower than permanent income the household borrows against future income to make up the difference. If credit markets are less than perfect the household may face limitation on their ability to fully smooth consumption. In essence, the saving level is too high if actual consumption differs from desired consumption. By allowing households to lower their savings rate, an IO mortgage is valuable if actual consumption differs from desired consumption. Moreover, less than perfect credit markets suggest that the household is borrowing less than optimal. If the household faces a payment-to-income constraint, where borrowing is limited by the payments on the mortgage relative to income, an IO mortgage also facilitates additional borrowing. An IO mortgage can thereby help alleviate credit constraints and move actual consumption closer to desired

\(^4\)For fully specified models with the constraint that we use here, see Greenwald (2017), Grodecka (2017) and Gorea and Midigan (2017).
consumption through both a reduction in savings and additional borrowing.

However, only households who are constrained change their consumption through an IO mortgage. To see this, note that if the household is already at their optimal consumption level a mortgage product that allows them to consume more is irrelevant. An IO mortgage may allow household to change the composition of savings, but as consumption was already at its desired level the new mortgage has no impact on the consumption level. For example, a household amortizing their mortgage may start investing in stocks or increase their pension savings in lieu of paying off the mortgage, which over time may increase consumption (Cocco, 2013). However, there is no immediate effect on consumption.\footnote{Note that without financial constraints, a household facing a regulatory requirement on amortizing their mortgage could borrow more, invest it into a savings account and make amortization payments from borrowed funds. In this way, any requirement can be completely negated and actual consumption will equal desired consumption (Svensson, 2016). This implies that the introduction of an IO loan may actually lower borrowing for unconstrained households, although the savings rate would be unchanged.}

In contrast, constrained household are affected because an IO mortgage can help loosen credit constraints and facilitate additional borrowing. While most models of financial constraints consider only a collateral or Loan-to-Value (LTV) constraint, IO mortgages does not directly affect the value of the collateral. However, an IO mortgage does allow for lower mortgage payments, which is relevant for households facing a Payment-to-Income (PTI) constraint for borrowing (Greenwald, 2017; Gorea and Midrigan, 2017; Grodecka, 2017). With a PTI constraint the sum of interest payments and amortization payments cannot exceed a fraction of current income. For instance, a household with a mortgage interest rate of 5 percent and a three percent amortization rate wishing to keep mortgage payments below 20 percent of income is limited to borrowing at most 2.5 times her income. With this constraint the cost for the mortgage directly affects borrowing, where lower costs lead to more borrowing. If amortization payments are removed through an IO mortgage, borrowing capacity increases to 4 times income.\footnote{Borrowing capacity 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.} Understanding how IO mortgages affect borrowing and consumption depends on whether the PTI constraint
is binding. Importantly, we can derive conditions for when the PTI constraint is more likely to be the binding constraint, which later will inform our empirical strategy.

Consider a constrained household that faces two separate constraints for the borrowing required to fund consumption. First, the value of the mortgage is limited by a LTV constraint given by \( M \leq \theta_H H \), where the household can borrow an amount \( M \) up to a fraction \( \theta_H \) of house value \( H \). Second, the household faces a PTI constraint \( (\gamma + r_m)M \leq \theta_Y Y \), where the sum of amortization payments, \( \gamma \), and interest payments, \( r_m \), cannot exceed a fraction \( \theta_Y \) of income \( Y \). We can rewrite the above constraints as:

\[
\bar{M}^{ltv} = \theta_H H \quad \bar{M}^{pti} = \frac{\theta_Y Y}{(\gamma + r_m)},
\]

where \( \bar{M}^{ltv} \) and \( \bar{M}^{pti} \) denotes the maximum borrowing given the LTV and PTI constraint, respectively. Since the minimum of the constraint will determine borrowing, we can write the overall debt limit \( \bar{M} \) as:

\[
\bar{M} = \min(\bar{M}^{ltv}, \bar{M}^{pti}).
\]

Since household borrowing capacity is subject to both constraints simultaneously, maximum 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 arrive at an equation for when the PTI constraint is binding:

\[
\frac{H}{Y} > \frac{\theta_Y}{\gamma + r_m \theta_H} \frac{1}{\theta_H} \tag{1}
\]

For sufficiently high values of house values to income, the PTI constraint will determine borrowing.\(^7\) Intuitively, for sufficiently high values of the house, it is the payments for borrowing that is binding, not the value of the collateral. In contrast to models with

\(^7\)If \( \bar{M}^{ltv} \) and \( \bar{M}^{pti} \) are equal, both constraint together determine borrowing.
only a LTV (e.g. Iacoviello, 2005), higher house values increases borrowing capacity. However, if the household also has the pay the costs for borrowing, at a certain threshold determined by equation (1) the household is not able to take advantage of higher collateral values. Determining which constraint binds is therefore crucial for understanding how IO mortgages will affect borrowing. If the PTI constraint is binding, lower amortization payments induce more borrowing and can raise consumption for constrained households. Intuitively, the higher the value of your house relative to your income, the more likely it is that it is the payments on the mortgage that matter, not the value of the collateral. However, if the household is unconstrained or if the LTV constraint is binding, lower amortization payments have no impact on consumption. We will use this intuition as the basis for our empirical strategy.

Note that for a household facing a PTI constraint, lower interest rates or lower amortization payments are functionally equivalent. In this sense, amortization payments represent a real constraint on borrowing, even though they are fundamentally not a cost but a form of savings. A household with a high housing wealth to income ratio is likely to face relaxed borrowing constraints from both lower interest payments and lower amortization payments.
Borrowing with a new PTI and LTV Constraint

Figure 4: Two Experiments

Notes: The figure on the left plots how borrowing differs for two different experiments. The blue solid line plots the loosens the PTI constraint (blue solid line) by setting amortization rates equal to zero, and raises house prices by 20 percent (red dashed line).

We illustrate this intuition in Figure 3.\textsuperscript{8} Consider a household who is facing borrowing constraint. She can borrow at most 80 percent of the value of her house, and faces a PTI limit of 20 percent of her income. Using the numbers from before, with an interest rate of 5 percent and amortization payments of 3 percent per year she can borrow at most 2.5 times her income. From equation (1) we have that for any house values above 3.125 times her income, the PTI constraint becomes the binding constraint.\textsuperscript{9} Any desired borrowing above this threshold is limited by the too high payments on mortgage debt. For any value below 3.125 times her income the LTV constraint is binding instead. If the household was only facing a LTV constraint, borrowing increases linearly in the value of collateral (the house value in this case).

Let us now consider two different experiments. The left hand of figure 4 plots how borrowing changes when we exogenously increase house values to income ratios by 20 percent (blue dashed line) and when we remove amortization requirements. The right hand side plots the change in borrowing against the initial house value to income ratios.

Specifically, we first set amortization payments are exogenously equal to zero, in-

\textsuperscript{8}Greenwald (2017) has a similar illustrative example for how an PTI constraint affects house prices.

\textsuperscript{9}From equation we have that the PTI constraint is binding if \( H/Y \) is greater than \( 0.2/(0.05 + 0.03) \times 1/0.8 = 3.125 \).
creasing the borrowing imposed by the PTI constraint to 4 times household income. We consider this to be analogous to the policy reform in Denmark in 2003, where amortization payments can be set to zero for the first 10 years by choosing an IO mortgage. In the figure, this correspond to a shift up of the red dashed line. With amortization payments now at zero the household is able to borrow $0.2/(0.05) = 4$ times her income, meaning that the borrowing limited by the PTI constraint increases by 1.5 times income. However, for house values below 3.125 times income, borrowing is not limited by the PTI constraint. The increase in borrowing below this threshold is therefore 0, as illustrated by the dashed line on the right hand side. Once house value to income reaches 3.125 times income, however, borrowing can increase. For certain values of house values to income, the binding constraints switch from PTI to TLV, creating an angled upwards slope of the red dashed line. In particular, in the areas where house value to income exceeds 5, the PTI constraint now binding. 10 Relaxing a slack constraint does not change borrowing, and therefore the increase in borrowing is zero up until the PTI constraint starts binding, at which point is goes quickly up to 4 times income, or 1.5 times income more than in the baseline scenario on the left hand side.

Our other experiment corresponds to a wealth effect from housing. Specifically, we exogenously increase house prices (blue solid line) by 20 percent. If the household has an initial house value to income ratio below 3.125, the value of the collateral has increased and the limited imposed by the LTV constraint has shifted up. Specifically, the household is able to borrow 80 percent of any increase in the value of her collateral. However, above certain values the PTI constraint instead starts to bind, and the increase in borrowing is decreasing until it hits zero at 3.125 times income, where the PTI constraint fully limits borrowing. Intuitively, the household has more collateral available for borrowing but she cannot afford the payment on the mortgage and thus cannot take advantage of higher house prices.

10 From equation (1), we have that: $0.2/0.05 \cdot 1/0.8 = 5$. 

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3 The Introduction of Interest-Only Mortgages

The Danish mortgage market consists of seven mortgage credit banks that provide mortgage loans to households and sell bonds to investors using the payments from the mortgage loans.\(^{11}\) These mortgage banks are legally limited in their product offering, and changes to the legal framework are implemented through regulatory reform voted on in the Danish parliament. The reform that legalized interest-only mortgages was introduced to the Danish parliament on March 12, 2003 and was voted through parliament on June 4. Mortgage banks were allowed to start selling their version of an IO mortgage, in Denmark referred to as a “deferred amortization” mortgage (afdragsfri lån). The purpose of the reform was to increase affordability for temporarily credit constrained households, such as students or individuals on maternity or paternity leave. The expected outcome of the reform was that IO loans would be a niche product, and that their introduction would not affect either house prices or consumption. The law quickly passed through parliament, gaining approval in June 4th with a large majority voting in favor.\(^{12}\)

Interest-only mortgages usually refer to products were amortization payments are postponed, and this is also the case in Denmark. The new product, which started selling in October 2003, allows a household to postpone amortization payments for up to 10 years.\(^{13}\) During this time, the household can still choose to pay down the mortgage or save in alternative assets. The maturity remained 30 years, which due to higher principal in the first 10 years implies that the total interest-payments are higher over the life time of the loan. Moreover, the law proposal specifically mandates that the mortgage banks inform their customers of both the higher costs and the higher risk associated with these products. In a 2011 survey of IO loan holders, 89 percent reported being “very well informed” or “well informed” about both the higher cost and the higher risk associated

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\(^{11}\) A comprehensive overview of the Danish mortgage market system can be found in Association of Danish Mortgage Credit Banks (2009), Danske Bank Markets (2013) and Campbell (2013, p. 28).

\(^{12}\) 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](https://www.retsinformation.dk/Forms/R0710.aspx?id=91430) and at [http://webarkiv.ft.dk/?samling=20021/lovforslag_oversigtsformat/L177.htm](http://webarkiv.ft.dk/?samling=20021/lovforslag_oversigtsformat/L177.htm).

\(^{13}\) Technically, the mortgage can have a 10-year period without amortization payments. The household can choose to refinance to a new IO loan when the first amortization-free period expires.
with their mortgage choice.

Against the expectation of policymakers, these new mortgages rapidly became a popular product. The left hand side of figure 5 plots outstanding mortgage debt, along with the fraction of IO mortgage. Mortgage debt increased rapidly in the years after IO mortgages were introduced together with the share of IO mortgage. Three years after the reform, close to a third of outstanding mortgage debt in Denmark was held in interest-only mortgages. To this day, IO mortgages remain a popular product, representing approximately 50 percent of outstanding mortgage debt. 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 the United Kingdom and the United States. Barlevy and Fisher (2011) and Amromin et al. (Forthcoming) find that IO mortgages essentially disappeared after the housing crash, and Cocco (2013) document that IO mortgages are 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.

In contrast to evidence from the United States, IO mortgages in Denmark were not limited to specific areas. Whereas Amromin et al. (Forthcoming) and Barlevy and Fisher (2011) report that IO mortgages were prominent in areas where house price growth was high, in Denmark these products were popular all over the country. In 2009, when we can reliably identify the specific type of mortgage debt across households, we find that the lowest penetration on the municipality level was 37 percent and that the highest was close to 70 percent. Although there is variation across municipalities, IO mortgages were essentially a popular choice throughout the country and not concentrated in areas that later experienced high house price growth.

However, these new products were not concentrated among low income borrowers. Instead, IO mortgages proved popular throughout the income, age and wealth distribution. This is in line with the finding in Amromin et al. (Forthcoming), who find that similar products in the United States were primarily used by sophisticated and high-income
borrowers with high credit scores. Figure 6 provides the result. Note that this graph includes only households with mortgage debt. IO mortgage use is slightly higher among younger households, is decreasing towards age 55, increasing as households approach the retirement at 65, and flattens out for households above the age of 65. The IO mortgage share is U-shaped in income, where both low income and high income households are more likely to hold an IO mortgage. Even so, IO mortgage remain a popular choice for all households.

4 Data, Methodology and Identification

We construct a dataset containing consumption expenditure, income, financial wealth, homeownership, mortgage choice, leverage, house prices, and demographic characteristics for all households in Denmark from 1996 to 2010 by aggregating individual-level information using a family identification number. Danish financial institutions report financial information about their customers for tax purposes to the Danish Tax and Customs

\footnote{All values are deflated to a base of 2006 using the consumer price index from Statistics Denmark.}
Administration (SKAT) at the end of the year. This reporting is mandatory, ensuring that we have a reliable overview of financial assets and liabilities for each individual in Denmark. This includes data on disposable income, and detailed information about financial assets and liabilities. Disposable income is a sum of income after taxes, interest payments, rental value of owned properties, alimony payments and repaid social benefits. Financial assets consist of individual holdings of stocks, bonds and bank deposits. Liabilities include separate categories for bank debt and mortgage debt.\footnote{A full variable description is available in the appendix.}

We augment these data with several other registers. First, we collect detailed demographic data including age, gender, education, municipality of residence, and the number and identity of any children. Second, labor market information include wage, industry, employment status. Third, we collect detailed information about each individual’s ownership of housing, including number of owned properties, property values and location of the owned property. We later merge house price growth based on location of the owned property. We use property transaction records collected from the Danish Official Gazette (Statistidende) to keep track of homeowners and their housing assets, and to construct a municipality-level house price index. As we observe all housing transactions, we can
therefore pinpoint households who passively benefit from house price changes, i.e. those who do not make an active decision to transact in the housing market.

Information on mortgage characteristics is available from Finance Denmark from 2009 and onwards. This dataset contains information from the 5 largest mortgage banks in Denmark with a total market share of more than 90 percent.\textsuperscript{16} Included in the register is individual-level information about each mortgage that the individual holds, including loan size, bond size, 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. As we observe the total loan size and not the individual’s share of the mortgage, we calculate a weight based on the number of individual 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.

Since this dataset is available starting in 2009, we use the origination date to assign the mortgage back in time. For each individual, we aggregate loan values and other characteristics based on the origination year of the mortgage, and then merge these characteristics back in time from 2009.\textsuperscript{17}

\textbf{Imputed Consumption Expenditure}

Our key outcome variable is consumption expenditure. We impute this variable based on information on income and changes in wealth. By definition, spending in a given year is equal to disposable income minus the increase in net wealth. Given that we can correctly observe these variables, we can compute consumption expenditure for individual \(i\) at time \(t\) as:

\[
Consumption\ Expenditure_{it} = \text{disposable income}_{it} - (net\ wealth_{it} - net\ wealth_{it-1})
\]

\textsuperscript{16}See Andersen et al. (2015) for more information about the registry.

\textsuperscript{17}With this procedure, we are unable to classify whether a mortgage is interest-only or not in the years prior to the most recent refinancing. In effect, the match is worse the further back in time we go, as households refinance to take advantage of lower interest rates.
This procedure has been used in several studies using Danish data (see e.g. Leth-Petersen, 2010; Browning et al., 2013; Jensen and Johannaes, 2016). More importantly, imputed consumption expenditure has been validated in several different studies by comparing imputed consumption expenditure to survey measures, and has generally performed well on average (Browning and Leth-Petersen, 2003; Kreiner et al., 2015).18

The main concern with imputed consumption is that changes in the valuation of items on the balance sheet will be measured as consumption. For example, unrealized capital gains on stock portfolio will be measured as consumption. Similarly, 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. This is not an issue for housing, where we can observe all property transactions. For a household that does not trade housing, any change in housing wealth is derived from price changes. Since we are interested in households who do not trade housing, we remove them 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 verify that our results are not affected by this procedure by examining households who do not hold any stock investments and therefore are not affected by the procedure. Second, an increase in the interest rate reduces the value of fixed interest mortgages, but does not affect valuation for adjustable rate mortgages. In a robustness check we therefore use only households with a variable rate mortgage.

We compare the resulting measure of consumption expenditure to the closest analogue to our sample in the Danish Expenditure Survey. Figure 7 shows that both imputed and survey-based consumption closely match in levels and growth rates, consistent with the

18See 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.
findings in Browning and Leth-Petersen (2003). The average annual total household consumption expenditure over the sample years is 428,000 DKK ($66,000). This amount is close to the value reported by the Danish Consumer Expenditure Survey for two-person households with children.

Sample and Variable Construction

We select all two-adult households between ages 22 and 55 years old (either married or cohabiting) who own housing assets. We remove households where at least one member is an entrepreneur, because income and wealth characteristics are less accurately reported for entrepreneurs. We also remove three small island municipalities as their housing and financial situation is likely different from the rest of Denmark.\footnote{The municipalities in question are Christiansø (78 inhabitants), Ærø (6,383 inhabitants) and Bornholm (39,664 inhabitants).} As explained above, we also remove households who buy or sell housing assets in year $t$ and $t - 1$ (Bemmeljch et al., 2017, find that household have higher consumption expenditure in the year following housing purchases). We remove outliers in consumption expenditure by excluding...
observations where the growth in imputed consumption expenditure is above the 99th percentile or below the 1st percentile, any observations with negative imputed consumption, and a small number of households who have no housing wealth but who have positive mortgage debt. Browning and Leth-Petersen (2003) find that imputed consumption corresponds well to the self-reported consumption on average, but that outlier values can be problematic.\footnote{Koijen et al. (2015) point to a similar issue for imputed consumption in Swedish administrative data.} We finally limit the sample to households who are present during all relevant years (from 2000 to 2010. a total of 11 years).

We construct a housing wealth to income ratio for each household using adjusted tax assessed housing wealth divided by disposable income. Housing wealth in the administrative data systematically underestimates actual housing wealth, which we address by a scaling factor. Specifically, we use calculate the scaling factor as the 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\footnote{Denmark Statistics calculates the same scaling factor, but we are unable to use theirs because of a 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.}, which we then multiply by the tax-assessed value we have available for each homeowner to attain a measure of the market value of housing wealth. Finally, we divide our measure by disposable income to get a value of Housing Wealth to Income.

We construct two variables related to credit constraints. First, we construct a measure of liquidity constraint as liquid assets divided by disposable income. Liquid assets consist of the sum of the market value for bonds, stocks and bank deposits. Second, we construct a measure of borrowing constraint as value of outstanding mortgage debt divided by housing wealth, which we refer to as leverage (LTV).

We examine whether household’s nominal mortgage balances increased by more than 10 percent year-over-year and interpret this as an indicator that a household extracted equity in the given year. This is the same threshold as in Andersen et al. (2015), who briefly discuss equity extraction in Danish data.\footnote{Bhutta and Keys (2016) chose a 5 percent threshold. We chose a higher threshold because mortgage debt is measured in market values in the data, which fluctuates year-over-year depending on interest}
4.1 Identification and Methodology

Our empirical strategy exploits cross-sectional variation in the \textit{ex ante} benefit of choosing an IO loan to isolate the effect of these new products on household consumption expenditure. Specifically, households with a low benefit from choosing an IO mortgage act as a control group for households with large benefits, allowing us to compare the consumption of the two groups to attain a causal effect of the policy and to construct a counter-factual of what would have happened in the absence of the policy.

Motivated by the conceptual framework, we measure the benefit of choosing an IO loan (henceforth “Exposure”) through the individual’s house value to income ratio in 2002, observed prior to the reform. We showed that IO mortgages are only valuable to households that are constrained, and that house value to income ratios are directly related to the likelihood that the household is constrained by mortgage payments (PTI constraint) instead of the collateral value. A higher house value to income makes it more likely that the PTI is binding, implying that the benefit of choosing an IO loan is higher.

Empirically, the fraction of IO mortgages is strongly increasing in housing wealth to income ratios, as shown in Figure 8. The figure plots the IO loan penetration against housing wealth to income, showing a strong positive correlation between IO mortgage share and housing wealth to income for binned bivariate averages, or “binscatters”.\textsuperscript{23} The same pattern appears 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, and if we focus on the sample that we use in the estimation. Moreover, this pattern does not only appear in Denmark, but also in the United States. Amromin et al. (Forthcoming) reports that complex mortgages, which consistent predominantly of IO mortgages, are more prevalent for households with high house value to income ratios, and that traditional mortgages were correspondingly less prevalent (see Figure 2 in the

\textsuperscript{23}We have used data from 2009 to measure IO mortgage penetration. We control for municipality and year of origination fixed effects when constructing the figure. The results are unchanged if we do not use any controls or if we focus on mortgage originated between 2004 and 2006.
above paper). Given the theoretical prediction from the previous section and the strong empirical correlation, we conclude that our measure of Exposure strongly predicts IO loan use. Furthermore, by ranking household prior to the reform we also avoid households selecting into high house value to income ratios in expectation of the reform.

Figure 8: Housing Wealth to Income and IO Loans

To implement the empirical strategy, we follow Berger et al. (2016) and Mian and Sufi (2012) and estimate the following cross-sectional regressions where we average observations for different time periods:

$$\frac{Consumption_{i,t} - T}{Consumption_{i,2000}} = \alpha + \beta Exposure_i + \gamma X_i + \epsilon_i, \quad (2)$$

where $Consumption_i$ is consumption for household $i$ in different time periods and $Exposure_i$ is measured as the housing wealth to income ratio in 2002, $\frac{Housing Wealh_{2002}}{Income_{2002}}$. We scale consumption by its 2000 value to estimate growth rates, similar to Berger et al. (2016). Due to the imputation procedure consumption expenditure is noisy and varies significantly across years. By averaging and scaling by prior values of consumption expenditure instead of using year-over-year changes we reduce noise and additionally avoid equity extraction in one year from unduly affecting consumption growth.\textsuperscript{24}

\textsuperscript{24}Andersen et al. (2016) illustrates this point. The authors show that households with high values of
We use control variables measured in 2002 and cluster standard errors at the municipality-level. We run the above regression for three different time period; 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 period to examine whether different house price regimes impact the results.\textsuperscript{25}

A concern with this approach is that observed or unobserved characteristics unrelated to the benefit of an IO mortgage may driving uptake. Where IO mortgages are popular is not random, and if these characteristics are correlated with time-varying shocks at the individual and geographical level, this poses a threat to identification. 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. Moreover, the introduction of IO mortgages may lead to changes in homeownership over the cycle, as households adapt their housing choice to the new mortgages. To address the last issue, we measure housing wealth to income prior to the mortgage reform to ensure that our measure is not conflated with homeownership decisions later in the business cycle.

To address unobserved characteristics affecting our estimation, we employ multiple strategies. First, we use growth rates in consumption, condition on year fixed effects, and report results with and without controls. Second, we provide extensive tests for parallel trends in the pre-treatment period. Third, we examine how the reform affected different components of consumption for different subgroups of the population. With an IO mortgage, a constrained household can increase borrowing and reduce savings and an unconstrained household can shift savings towards different assets. By examining if different components of consumption respond in a manner consistent with the theoretical

\textsuperscript{25}We also use a standard difference-in-difference setup following Bertrand \textit{et al.} (2004). The different setup does not affect the results, which are available in the appendix.
predictions, we increase our confidence that we are in fact identifying the effect of IO loans on consumption. This includes testing for differing growth rates in income, which could indicate that the business cycle affected households in the two groups differently. Fourth, we explicitly control and test for housing wealth effects, as house price growth is higher in areas with higher benefits of IO mortgages. All these results, combined with the theoretical framework, increase our confidence that we are identifying the effect of IO mortgages on consumption.

5 The Effect of IO Mortgages on Consumption

5.1 Main Results

We begin by showing our main result graphically: consumption expenditure increased more for households with higher ex-ante exposure to IO mortgages, a result that does not reverse over time. Figure 9 plots the coefficients on $Exposure$ from cross-sectional regressions for each year.\footnote{Results from a standard difference in difference framework where we include household fixed effects and interact a dummy for above-median $Exposure$ with year dummies is presented in Figure 12 in the appendix.}

The pre-trend for the two groups is not statistically different, but after IO mortgages are introduced the coefficient on $Exposure_i$ becomes positive and statistically significant. Consumption is consistently higher for the group most exposed to IO loans, even after house prices decrease in 2008 and 2009. This suggest that there was no reversal in consumption, consistent with an increased consumption level over time. However, this pattern is not consistent with short-term shocks affecting consumption, such as business cycle effects, income expectations or housing wealth effects, as those revert back once the economy and housing market declines in 2008 and 2009.

We provide additional evidence on the effect of higher Exposure on consumption growth in Figure 10 using an exercise from Berger et al. (2016). Specifically, we plot scaled consumption for 100 percentiles based on pre-reform housing wealth to income.
Figure 9: Consumption Expenditure by Exposure

*Note:* The figure plots the coefficients on *Exposure* from a regression of \( \frac{\text{Consumption}_{it}}{\text{Consumption}_{2000}} = \alpha + \beta \text{Exposure}_i + \epsilon_t \). 95 percent confidence intervals are marked with dashed lines. Standard errors are clustered on the municipality level.

The vertical axis shows households sorted by their 2002 values, and the horizontal axis shows to years. A higher value on the vertical axis corresponds to a higher housing wealth to income ratio in 2002 and thereby a higher exposure to the benefits of IO mortgages. Each cell shading shows the value of the key outcome variable, consumption scaled by its 2000 value. This approach allows us to perform the traditional graphical pre-trend comparisons between different groups for the full distribution of the population. In effect, each cell corresponds to a difference-in-difference regression, and we use the relative shading prior to the introduction of IO mortgages in 2003 to examine different pre-trends in consumption growth.

The figure shows that consumption growth is similar across groups prior to the introduction of IO mortgages in late 2003, but that consumption increases for the households that most benefit from the reform in 2004 and especially in 2005. Prior to 2004, the parallel trends in consumption growth suggest that the assumption behind the empirical strategy is valid. Consumption growth in 2005 appears to be monotonically increasing in ex-ante benefit of choosing an IO mortgage, suggesting that the results are not driven by outliers. Moreover, it does not appear that the impact of IO mortgages is short-lived.
This is consistent with a higher consumption-level from choosing an IO mortgage, or opposite a consistently lower savings rate over time. A one-time shift up in consumption is consistent with choosing an IO loan to lower savings rates, but is less consistent with one-time changes due to increased borrowing in one period, temporary income shocks or business cycle effects. For instance, Anderson et al. (2016) find that households borrowed to fund durable consumption in one year, leading to a short-term increase but also to a reversal.

Table 2 provides the estimates of Equation (2) for different time period. Specifically, the first row estimates a cross-sectional regression of consumption scaled by its 2000 value for different time periods. Column 1 provides the results without control variables, Column 2 includes controls for demographics and regional fixed effects, Column 3 and 4 restricts the sample to young and old households, respectively. The final columns restrict the sample to areas with high (column 5) and low (column 6) house price growth during the housing boom.

In the Pre-Reform period we find no statistically or economically significant positive differences in consumption growth depending on Exposure. The results in Column 1
suggest that there are no differences in consumption growth, whereas the coefficient in Column 2 when we include controls show a negative coefficient – in the pre-reform period higher exposure predicts lower consumption growth after controlling for demographic characteristics measured in 2002. The estimates are also fairly small in magnitude.

In the Early Post Reform period, higher Exposure predicts higher consumption, consistent with the results in the above figures. Quantitatively, the effect was to increase consumption expenditure by 2.4 percent in the Early Post-Reform and by 5 percent in the Late Post-Reform period for each standard deviation increase in Exposure. Consumption expenditure is consistently higher and shows no sign of reversing, even as house price growth is negative in 2008 and 2009 and the macroeconomic environment becomes unfavorable. These results are stable across different specifications.

We provide several results where we restrict the sample for several reasons. Recall that the benefit of an IO mortgage in terms of consumption relies on financial constraints, and that in the absence of these constraints we do not expect to see an effect on consumption. Motivated by this prediction, we test whether groups that are more or less likely to be financially constrained reacted differently. We divide our sample into different groups and run different regressions for each group, thereby allowing for different time trends for the group at large. We begin by dividing the population according to age to proxy for financial constraints (Campbell and Cocco, 2007). In the Early Post Reform period the coefficient on young households in Column 3 is small and marginally statistically significant, whereas the coefficient for Old households in Column 4 is larger and strongly significant. In the the Late Post Reform period, the coefficients are similar across the age groups.

In Column 5 and 6 we split the sample according to the housing price growth during the boom. Specifically, we divide municipalities into four groups according to the house price growth during the boom, and estimate the results for Exposure on the sample of the households that lived in municipalities with the highest (lowest) quartile of house price growth in Column 5 (Column 6). The estimated coefficients are very similar in
magnitude, especially in the Late Post Reform period. It is therefore not likely that our results are driven by differential growth in house prices. We return to the issue of house price growth and consumption later.

The results therefore suggest that households more likely to hold IO mortgages experienced higher growth in consumption, and that this is likely not driven by house price growth differences.

5.2 Components of Consumption

We proceed to examine the components of consumption separately in Table 3. This exercise allows us to examine different trends in income growth depending on Exposure, and to understand how consumption expenditure increases. We report results from a cross-sectional regression with the outcome variable in columns and the time period in the rows. Specifically, we estimate regressions of the form:

$$\frac{z_{i,t+T}}{z_{i,2000}} = \alpha + \beta Exposure_i + \gamma X_i + \epsilon_i, \tag{3}$$

where $z_i$ is the component of consumption. In our case we include disposable income, total assets and total debt. We also include a different measure of income, personal income, which measures total income obtained by the household. We include the same control variables as in Column 2 of Table 2 and municipality fixed effects.

We begin in Column 1 with Personal Income as the outcome variable. Personal Income growth in the Pre-Reform Period was lower for more exposed households, although the coefficient is small in magnitude. The same result holds for Column 2, where we use Disposable Income as the outcome variable. Overall, there does not appear to be any substantial differences in income growth depending on Exposure in the Pre-Reform period. We do find significant differences in Personal Income Growth later in the cycle, which may explain a part of the larger coefficient on consumption that we observed in the previous table.
Note that we are using a measures of the total income of the household (Personal Income) and a measure of income after interest payments, (Disposable Income). For the consumption expenditure imputation we use Disposable Income, as this measures what the household actually can use. Our goal with this exercise is to determine whether Exposure is correlated with higher income growth, which would suggest that the business cycle affects highly exposed households differentially. In this case, Disposable Income is an endogenous variable that depends directly on mortgage choice. A positive coefficient on this variable therefore does not rule out the importance of PTI constraints.

Column 3 examines total assets, which consists of stocks, bonds and cash deposits. The coefficients for the Pre-Reform period shows show a positive coefficient on total assets for all households, although it is only marginally significant. In the two Post Reform periods we find coefficients an order of magnitude larger, suggesting that households more exposed to the reform increased their asset holdings. Column 4 examines total debt, which includes mortgage and bank debt. The positive coefficient in the Pre-Reform period shows higher debt growth based on Exposure. In the Post-Reform periods we find somewhat larger estimates, suggesting that mortgage debt and total debt increased more for households more exposed to the reform.

6 Robustness to Alternative Explanations

In this section we explore additional explanations that could explain the link between consumption and Exposure. The first explanation is related to housing wealth effects. Indeed, a plausible interpretation of the above results is that they are driven by wealth effects, since the households more exposed to the reform also experienced higher growth in house prices. However, we will argue that it is more likely that IO mortgages are driving consumption higher in areas where house price growth was higher. Although we do not make any claim on IO loans causing house price growth here, we argue that it is unlikely that house price growth caused higher consumption growth in our context.
First, note that if house price shocks were driving the results, we would expect a negative coefficient in the Late Post Reform period (2007-2010) as house prices declined dramatically during this period Mian et al. (see e.g. 2013). Additionally, the results presented in Table 2 for municipalities with different house price growth during the boom and the fixed effects for municipalities also alleviates concerns over wealth effects driving the results. Note that municipality fixed effects also helps alleviate concerns over different income expectations or labor market effects by removing any common shock.

However, there may still be heterogeneity in the response to house price growth that is not captured by municipality fixed effects.\textsuperscript{27} We therefore provide evidence that housing wealth effects have not been a factor for Danish households except in the period when IO mortgages became prominent. Consistent with previous results in Browning et al. (2013) for 1987-1996, we show that house price growth is uncorrelated with consumption growth in all periods, except for the period when IO mortgages became prominent. These results hold for various subgroups, including standard proxies for liquidity and borrowing constraints – for no group that we examine, house price growth had a positive impact on consumption expenditure prior to 2003. It appears to more plausible that IO mortgages are driving consumption growth in the areas where house price growth was high, not that wealth effects are important. Our conclusion from this exercise is therefore that IO mortgages are driving consumption growth, as indeed they were designed to do and theory predicts, not that house price growth was driving consumption.

Table 4 provides estimates of the correlation between house price growth and consumption growth for different time periods. Specifically, we follow previous studies (Browning et al., 2013), and estimate the following equation:

\[
\Delta\text{Consumption}_{ikt} = \alpha_0 + \alpha_1(HPgrowth_{kt}) + \alpha_3(\DeltaIncome_{ikt}) \\
+ \alpha_2(r_{ikt}) + \gamma X_{ikt} + \lambda z_t + \epsilon_{ikt}, \tag{4}
\]

\textsuperscript{27}For example, credit constraints imply that wealth effects vary across households, which would not be captured by municipality-year fixed effects.
for household $i$ in municipality $k$ and period $t$. In the above equation $\Delta Consumption_{ikt}$ is the log-difference in total consumption expenditure between period $t$ and $t-1$, $HPgrowth_{ikt}$ is the log-difference in house prices between periods $t-1$ and $t$ for municipality $k$. $\Delta Income_{ikt}$ is the log-difference in disposable income, and $r_{ikt}$ is the inter-temporal interest rate between periods $t-1$ and $t$. $X_{ikt}$ is a set of control variables that include changes in demographic characteristics between periods $t-1$ and $t$. We include a full set of region-year ($\lambda_{i}$) fixed effects to account for aggregate effects. We later interact all variables with different constraints to estimate results for households more likely to benefit from house price growth.

The first column estimates the baseline equation for the full sample of households without any controls. The estimated elasticity of consumption with respect to house price growth is 0.151, and is highly significant. When we control for income growth, demographic characteristics and year-region fixed effects, the coefficient is reduced to 0.038 in Column 2. However, the three remaining columns show that this result is entirely driven by the time period when IO mortgages were introduced.28 Specifically, Column 3-5 provide the results for different time periods, and show that consumption is uncorrelated with house price growth in years before and after the housing boom. In Column 3 the estimates are not statistically significant and is negative. In Column 4 the estimated coefficient of 0.081 is substantially larger and is strongly significant. In Column 5 the estimate is once again not significant and is indeed close to zero. These results suggest that the correlation between house prices and consumption expenditure is driven by a few years with high house price growth that followed the introduction and increased use of interest-only mortgages. If the adoption of interest-only mortgage results in the increase in consumption in the areas where house price growth was high, the higher coefficients in column 4 represents the increased importance of new mortgage products, not a causal effect of house prices on consumption.

28 All results are robust to excluding stock and bond holders, which may contain some measurement error due to imputation of stock holdings, and are robust to only including households who stay in the panel for more than 7 years. The results are also robust to normalizing consumption expenditure by disposable income.
Figure 11: Year-by-Year Estimates

Note. The figure plots the coefficients on $HP_{growth_{i,t}}$ interacted with year. Dependent variable is the change in log consumption. Regressions are estimated using controls for changes in income, demographic controls for age, education, change in family size, and region fixed effects. Standard errors clustered on municipality-year level.

Figure 11 shows the year-by-year results from a single regression, with very similar results. The estimate in column 3 for 1998-2002 is 0.040, but it is not statistically different from zero. During this period house price growth was relatively modest and there were no instances of serious financial innovations.

These results also hold for different proxies for financial constraints, provided in Table 5. We divide the population into quintiles based on leverage and liquid wealth for each year, and estimate separate coefficients on house price growth for each quintile. In contrast to the previous literature, we do not find that a low level of liquidity is associated with a larger response to house price changes in the periods prior to the introduction of interest-only mortgages (see e.g. Mian and Sufi, 2011, 2014, who finds that the housing wealth effect is primarily driven by households with low levels of liquidity). House price growth did not positively affect consumption growth for any quintiles in any year except for the IO mortgage reform period. Therefore, the only period where we observe positive and significant correlations between house price growth and consumption expenditure is in the period where IO mortgages were introduced.

These results echo what Browning et al. (2013) found for Danish households between 1987 and 1996, including the results for liquidity. Their conclusion is that housing wealth
effects are negligent in Denmark, which our results also indicate. We find very similar results for the different time periods if we use equity withdrawal as our outcome variable as in Bhutta and Keys (2016). It therefore does not seem likely that changes in house prices can explain the increase in consumption among Exposed households that we observe.

7 Conclusion

In this paper we have examined the impact of interest-only mortgages for consumption growth. Using a measure of exposure to the mortgage reform observed prior to the introduction of the new mortgage products, we estimate that the introduction of IO mortgages had a positive and significant impact on household consumption and borrowing.

Our results suggest that changing amortization requirements can have large impacts on both consumption expenditure by allowing a one-time upward adjustment in the consumption level. If a large enough number of households choose to refinance at the same time, this one-time adjustment will have a substantial impact on aggregate consumption. Both additional borrowing and the lower amortization rate will lead to a one time adjustment and a higher level of consumption, but the aggregate effect will dissipate as more and more households have already refinanced. However, this suggests that after the initial shock to consumption has expired, the presence of interest-only mortgages as an option will not affect aggregate consumption dynamics. It is precisely the introduction and increased popularity of these mortgages that created a boom in house prices and consumption in Denmark, not the availability of these mortgages. Indeed, forcing households to increase their savings by forcing them to start amortizing again may negatively impact consumption growth in the aggregate.

The results provide important new evidence on the cause of the financial crisis. In particular, the prevalence of IO mortgage across the income distribution suggest that financial innovation is valuable to a large share of the population. This fact can potentially explain the increase in borrowing throughout the income distribution observed during the
housing boom in the United States that Adelino et al. (2016) and Foote et al. (2016) finds.

Moreover, these results have important implications for the estimation of housing wealth effects. We provide new evidence that financial innovation can affect consumption expenditure, and that the effect will vary across locations. Importantly, the variation that determines the benefit of choosing an IO mortgage is highly correlated with housing supply through price levels.
References


Cloyne, James, Ferreira, Clodomiro, and Surico, Paolo. 2016. Monetary policy when households have debt: new evidence on the transmission mechanism.


8 Tables
Table 1: Summary Statistics

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<td>Housing Wealth</td>
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<td>1,202,111</td>
<td>1,611,716</td>
<td>2,221,629</td>
<td>832,014***</td>
</tr>
<tr>
<td></td>
<td>(280,401)</td>
<td>(316,661)</td>
<td>(459,772)</td>
<td>(758,616)</td>
<td>[66]</td>
</tr>
<tr>
<td>Housing Wealth to Income</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>2***</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(1)</td>
<td>[530]</td>
</tr>
<tr>
<td>Liquid Assets</td>
<td>124,263</td>
<td>126,697</td>
<td>145,581</td>
<td>186,018</td>
<td>35,276***</td>
</tr>
<tr>
<td></td>
<td>(298,222)</td>
<td>(218,419)</td>
<td>(245,762)</td>
<td>(307,884)</td>
<td>[29]</td>
</tr>
<tr>
<td>Interest Payments</td>
<td>42,502</td>
<td>52,533</td>
<td>58,047</td>
<td>59,808</td>
<td>11,105***</td>
</tr>
<tr>
<td></td>
<td>(26,193)</td>
<td>(28,711)</td>
<td>(32,991)</td>
<td>(39,801)</td>
<td>[78]</td>
</tr>
<tr>
<td>Consumption Growth 2002-2006</td>
<td>0.06</td>
<td>0.08</td>
<td>0.10</td>
<td>0.13</td>
<td>0.04***</td>
</tr>
<tr>
<td></td>
<td>(0.38)</td>
<td>(0.38)</td>
<td>(0.39)</td>
<td>(0.42)</td>
<td>[20.05]</td>
</tr>
<tr>
<td>Personal Income Growth</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.00</td>
<td>-0.00**</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.17)</td>
<td>(0.18)</td>
<td>(0.22)</td>
<td>[2.85]</td>
</tr>
<tr>
<td>IO Mortgage Dummy</td>
<td>0.32</td>
<td>0.40</td>
<td>0.49</td>
<td>0.59</td>
<td>0.18***</td>
</tr>
<tr>
<td></td>
<td>(0.47)</td>
<td>(0.49)</td>
<td>(0.50)</td>
<td>(0.49)</td>
<td>[64.61]</td>
</tr>
<tr>
<td>Liquid assets to income</td>
<td>0.31</td>
<td>0.33</td>
<td>0.38</td>
<td>0.51</td>
<td>0.11***</td>
</tr>
<tr>
<td></td>
<td>(0.51)</td>
<td>(0.52)</td>
<td>(0.58)</td>
<td>(0.77)</td>
<td>[40.24]</td>
</tr>
<tr>
<td>Mortgage to income</td>
<td>1.21</td>
<td>1.68</td>
<td>1.96</td>
<td>2.21</td>
<td>0.60***</td>
</tr>
<tr>
<td></td>
<td>(0.81)</td>
<td>(0.92)</td>
<td>(1.10)</td>
<td>(1.46)</td>
<td>[123.07]</td>
</tr>
<tr>
<td>Equity Extraction</td>
<td>0.14</td>
<td>0.16</td>
<td>0.18</td>
<td>0.18</td>
<td>0.03***</td>
</tr>
<tr>
<td></td>
<td>(0.35)</td>
<td>(0.36)</td>
<td>(0.38)</td>
<td>(0.39)</td>
<td>[17.52]</td>
</tr>
<tr>
<td>Mortgage Rate</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.06</td>
<td>-0.00***</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.04)</td>
<td>(0.04)</td>
<td>(0.04)</td>
<td>[-10.96]</td>
</tr>
<tr>
<td>Interest payments to Income</td>
<td>0.08</td>
<td>0.10</td>
<td>0.11</td>
<td>0.12</td>
<td>0.02***</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.06)</td>
<td>(0.07)</td>
<td>[79.61]</td>
</tr>
<tr>
<td>Liquidity Constrained</td>
<td>0.45</td>
<td>0.43</td>
<td>0.38</td>
<td>0.31</td>
<td>-0.09***</td>
</tr>
<tr>
<td></td>
<td>(0.50)</td>
<td>(0.49)</td>
<td>(0.48)</td>
<td>(0.46)</td>
<td>[-38.58]</td>
</tr>
<tr>
<td>Borrowing Constrained</td>
<td>0.62</td>
<td>0.63</td>
<td>0.57</td>
<td>0.43</td>
<td>-0.11***</td>
</tr>
<tr>
<td></td>
<td>(0.48)</td>
<td>(0.48)</td>
<td>(0.50)</td>
<td>(0.50)</td>
<td>[49.28]</td>
</tr>
</tbody>
</table>

Observations: 58114  60015  50872  30135  199148

Notes:
Table 2: Main Results – Consumption by Exposure for Different Time Periods

<table>
<thead>
<tr>
<th></th>
<th>(1) No Controls</th>
<th>(2) Controls</th>
<th>(3) Young</th>
<th>(4) Old</th>
<th>(5) High Growth</th>
<th>(6) Low Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Reform (2001-2003)</td>
<td>0.001</td>
<td>-0.005**</td>
<td>-0.015***</td>
<td>-0.002</td>
<td>-0.008*</td>
<td>-0.000</td>
</tr>
<tr>
<td>Observations</td>
<td>195,258</td>
<td>195,258</td>
<td>75,079</td>
<td>120,179</td>
<td>53,915</td>
<td>43,212</td>
</tr>
<tr>
<td>Early Post Reform (2004-2006)</td>
<td>0.024***</td>
<td>0.022***</td>
<td>0.007*</td>
<td>0.027***</td>
<td>0.021***</td>
<td>0.024***</td>
</tr>
<tr>
<td>Observations</td>
<td>195,135</td>
<td>195,135</td>
<td>74,835</td>
<td>120,300</td>
<td>53,984</td>
<td>42,983</td>
</tr>
<tr>
<td>Late Post Reform (2007-2010)</td>
<td>0.034***</td>
<td>0.050***</td>
<td>0.041***</td>
<td>0.051***</td>
<td>0.051***</td>
<td>0.050***</td>
</tr>
<tr>
<td>Controls</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>195,069</td>
<td>195,069</td>
<td>74,819</td>
<td>120,250</td>
<td>53,957</td>
<td>42,957</td>
</tr>
</tbody>
</table>

Notes: *, **, *** denote statistical significance at the 5%, 1% and 0.1% level. Standard errors clustered on municipality in parentheses.

Table 3: Components of Consumption for Different Time Periods

<table>
<thead>
<tr>
<th></th>
<th>(1) Personal Income</th>
<th>(2) Disposable Income</th>
<th>(3) Total Assets</th>
<th>(4) Total Debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Reform (2001-2003)</td>
<td>-0.011*** (0.001)</td>
<td>-0.008*** (0.001)</td>
<td>0.033* (0.016)</td>
<td>0.014*** (0.001)</td>
</tr>
<tr>
<td>Observations</td>
<td>792,961</td>
<td>792,768</td>
<td>774,816</td>
<td>773,902</td>
</tr>
<tr>
<td>Early Post Reform (2004-2006)</td>
<td>0.000 (0.001)</td>
<td>0.021*** (0.001)</td>
<td>0.125*** (0.033)</td>
<td>0.016*** (0.004)</td>
</tr>
<tr>
<td>Observations</td>
<td>588,050</td>
<td>588,868</td>
<td>576,559</td>
<td>575,906</td>
</tr>
<tr>
<td>Late Post Reform (2007-2010)</td>
<td>0.013*** (0.001)</td>
<td>0.042*** (0.001)</td>
<td>0.161*** (0.030)</td>
<td>0.022*** (0.005)</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>765,111</td>
<td>765,032</td>
<td>766,959</td>
<td>764,154</td>
</tr>
</tbody>
</table>

Notes: *, **, *** denote statistical significance at the 5%, 1% and 0.1% level. Standard errors clustered on municipality in parentheses.
Table 4: Baseline Results

<table>
<thead>
<tr>
<th></th>
<th>(1) All Years</th>
<th>(2) Controls</th>
<th>(3) 1998-2002</th>
<th>(4) 2003-2006</th>
<th>(5) 2008-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Price Growth</td>
<td>0.151***</td>
<td>0.038**</td>
<td>-0.008</td>
<td>0.081***</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.031)</td>
<td>(0.017)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>Income Growth</td>
<td>0.414***</td>
<td>0.430***</td>
<td>0.398***</td>
<td>0.429***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.012)</td>
<td>(0.008)</td>
<td></td>
<td>(0.009)</td>
</tr>
<tr>
<td>Education Length</td>
<td>0.001***</td>
<td>0.001***</td>
<td>0.001***</td>
<td>0.001***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td></td>
<td>(0.000)</td>
</tr>
<tr>
<td>Change in Number of Children</td>
<td>0.010***</td>
<td>0.009***</td>
<td>0.010***</td>
<td>0.012***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td></td>
<td>(0.002)</td>
</tr>
<tr>
<td>Household Specific Return</td>
<td>0.079***</td>
<td>0.137***</td>
<td>-0.007</td>
<td>0.095***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.015)</td>
<td>(0.010)</td>
<td></td>
<td>(0.010)</td>
</tr>
<tr>
<td>Apartment</td>
<td>0.002</td>
<td>0.013***</td>
<td>-0.001</td>
<td>-0.005</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td></td>
<td>(0.004)</td>
</tr>
<tr>
<td>Age Dummies</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Region-Year Interactions</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>2,185,036</td>
<td>2,168,046</td>
<td>584,949</td>
<td>988,846</td>
<td>594,251</td>
</tr>
</tbody>
</table>

Notes: *, **, *** denote statistical significance at the 5%, 1% and 0.1% level. Standard errors clustered on year-municipality in parentheses. Dependent variable is the change in log consumption, ΔConsumption_{i,k,t}. ΔHPI_{i,k,t} is the change in log square meter price between t – 1 and t for municipality k. Δy_{i,k,t} is the change in log disposable income between t – 1 and t. Regressions in column 2-5 include controls for age, education level, change in number of children, a household-specific individual return, and with region, year and region-year effects.
Table 5: Consumption and House Price Growth for Constrained and Unconstrained Households

<table>
<thead>
<tr>
<th></th>
<th>Leverage</th>
<th>Liquidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) 1998-2002</td>
<td>(2) 2003-2005</td>
</tr>
<tr>
<td>Quintile 1 X House Price Growth</td>
<td>-0.028 (0.054)</td>
<td>0.098*** (0.023)</td>
</tr>
<tr>
<td>Quintile 2 X House Price Growth</td>
<td>-0.012 (0.046)</td>
<td>0.092*** (0.024)</td>
</tr>
<tr>
<td>Quintile 3 X House Price Growth</td>
<td>0.037 (0.033)</td>
<td>0.036 (0.033)</td>
</tr>
<tr>
<td>Quintile 4 X House Price Growth</td>
<td>-0.024 (0.045)</td>
<td>0.135*** (0.039)</td>
</tr>
<tr>
<td>Quintile 5 X House Price Growth</td>
<td>0.031 (0.059)</td>
<td>0.412*** (0.076)</td>
</tr>
</tbody>
</table>

|                                |                   |                   |                   |
| Quintile 1 X House Price Growth| 0.016 (0.037)    | 0.038 (0.036)    | 0.045 (0.027)    |          |          |          |
| Quintile 2 X House Price Growth| 0.019 (0.040)    | 0.047 (0.027)    | 0.006 (0.020)    |          |          |          |
| Quintile 3 X House Price Growth| -0.030 (0.035)   | 0.104*** (0.024) | 0.018 (0.023)    |          |          |          |
| Quintile 4 X House Price Growth| -0.018 (0.048)   | 0.127*** (0.033) | 0.006 (0.021)    |          |          |          |
| Quintile 5 X House Price Growth| 0.007 (0.067)    | 0.210*** (0.032) | -0.037 (0.038)   |          |          |          |

Observations: 584,264 789,594 790,455 584,872 790,960 791,925

Notes: *, **, *** denote statistical significance at the 5%, 1% and 0.1% level. Standard errors clustered on year-municipality in parentheses. Column 1-3 include results for Liquidity Constrained households, and column 4-6 include results for Borrowing Constrained households. Dependent variable is the change in log consumption, $\Delta Consumption_{kt}$. $\Delta HPI_{kt}$ is the change in log square meter price between $t-1$ and $t$ for municipality $k$. $\Delta y_{kt}$ is the change in log disposable income between $t-1$ and $t$. All regressions include controls for age, education level, change in number of children, a household-specific individual return, and with region, year and region-year effects.
A Appendix

A.1 Variable Description

The registry data contains information on demographic characteristics, income, and dis-aggregated wealth variables for all households. Demographic characteristics on individual level include marital status, number of children, years of education, age, and area of residence. We define household level education as the level achieved by the most educated spouse, and household age as the age of the oldest spouse. We define a household as an owner if his/her registered housing wealth is positive. To measure housing wealth and leverage we use an official property valuation from SKAT, adjusted by a scaling factor to approximate market values.\(^{29}\)

A.2 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 (Statistik), 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.\(^{30}\)

After collecting the data on all property transactions, we connect each house and

\(^{29}\)The scaling factor is calculated as the sales price divided by the tax valuation for all sold properties, for each municipality, year and property type (single-family houses and apartments). A similar scaling factor is provided by Denmark Statistics for the years before 2006. For the years after the Danish municipality reform of 2006 we calculate this factor ourselves. We do not find substantial differences between the scaling factor that we calculate and the one provided by Denmark Statistics for the data directly comparable before and after the reform. See Andersen et al. (2016) for a similar calculation of housing wealth.

\(^{30}\)Removing family trades and similar non-market transactions are common in the construction of real estate indices. See e.g. the S&PCase-Shiller index methodology: http://us.spindices.com/index-family/real-estate/sp-case-shiller).
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.

A.3 Alternative Specifications

This section provides the results from alternative specifications for the impact of IO mortgage on consumption. First, we estimate how consumption responds to the ex-ante benefit of choosing an IO mortgage by estimating a difference in difference regression. In the baseline case, we divide the population into two groups based on housing wealth to income in 2002. Specifically, we call a household Exposed if their housing wealth to income in 2002 is above the median, and estimate the following regression:

$$\log Y_{it} = \alpha_i + \beta_1 PostReform + \beta_2 Exposed_i \times PostReform + \gamma X_i + \epsilon_i$$

where $\log Y_{it}$ represent consumption and its different components, $\alpha_i$ is a household-specific fixed effect, $PostReform$ is a dummy equal to one for all years after 2002, and $Treated_i$ is a dummy equal to one for all households with an above median housing wealth to income ratio in 2002. In specifications with controls, $X_i$ is a set of controls including household demographic characteristics measured in 2002 and regional fixed effects.

The first set of results are presented graphically.
Figure 12: Above Median Exposure and Consumption Expenditure