Mortgage Decisions of Households

Consequences for Consumption and Savings

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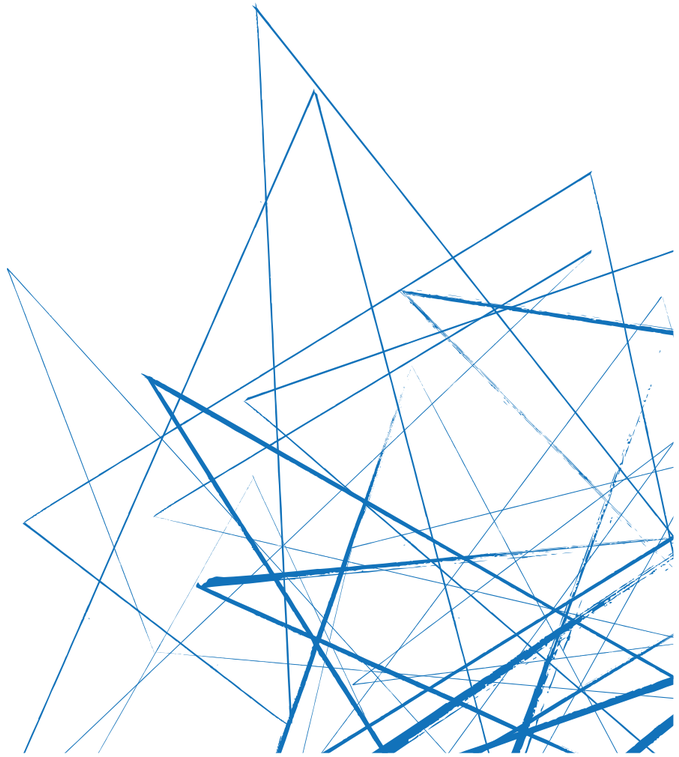

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PhD Series 06.2022

Rikke Sejer Nielsen

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HANDELSHØJSKOLEN

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Consequences for Consumption and Savings

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Rikke Sejer Nielsen, 2021

Abstract

This PhD thesis addresses three financial problems regarding the mortgage choice of the household and its effect on household consumption and savings.

The first chapter, *How do Interest-only Mortgages Affect Consumption and Saving over the Life Cycle?*, examines how the financial flexibility offered by interest-only (IO) mortgages affects households' consumption and saving decisions over the life cycle. This paper is resubmitted to the academic journal *Management Science*. Using a unique data set with detailed information on Danish households and their mortgages, we show that young and old households are more likely to use IO mortgages compared to middle-aged households. Young households use IO mortgages because they expect higher future income, old households because IO mortgages allow them to circumvent an otherwise binding liquidity constraint. Through different channels, IO mortgages thus facilitate consumption smoothing for young and old households. Our detailed data also allow us to examine how households with IO mortgages differ from households with repayment mortgages in terms of leverage, debt and asset composition, and pension contributions.

The second chapter, *The end is near: Consumption and saving decisions at the end of interest-only periods*, studies the consumption behavior of IO borrowers around the end of IO periods, where amortization starts or a refinance takes place. Using Danish register-based household data on IO borrowers containing detailed information on their mortgages, we find a positive average consumption response when the borrower refinances to a new IO mortgage, whereas it is negative in response to starting amortization. For households with expiring IO mortgages, we show a significant variation in the consumption response across age and level of consumption during the IO period, indicating that consumption smoothing over the mortgage life depends on these borrower characteristics. Young borrowers use the extra liquidity in the IO period to repay bank debt, whereas others mostly tend to use it on consumption. At expiration, we find that either borrowing constraints *force* IO borrowers to start amortization rather than rollover to a new IO mortgage, or IO borrowers start amortization *voluntarily* to minimize the cost of debt. Our findings have implications for regulation of IO mortgages.

The third chapter, *Double Jeopardy: Households' consumption responses to shocks in stock* and *mortgage markets*, investigates how household consumption is affected by shocks in the stock and

the mortgage markets. Households adjust consumption downwards following negative shocks to their stock holdings. Households also lower consumption following exogenous increases in mortgage debt payments. But what is the impact of simultaneous adverse shocks in both markets, such as in the 2008 financial crisis? Using detailed Danish household data we find that the reduction in consumption doubles if households are highly exposed to both the stock and the mortgage market. We also find that the negative effects persist over time. It has a severe effect on consumption as households with a high-risk profile in the asset market also tend to have high exposure in the debt market. We discuss underlying reasons behind our results and their implications for macroprudential policies.

Resumé (Danish abstract)

Denne afhandling behandler tre finansielle problemstillinger omhandlende husholdningens valg af realkreditlån og dets effekt på husholdningens forbrug og opsparinger.

Det første kapitel, *How do Interest-only Mortgages Affect Consumption and Saving over the Life Cycle?*, undersøger hvordan den finansielle fleksibilitet, som afdragsfrie realkreditlån tilbyder, påvirker husholdningers' forbrugs- og opsparingsbeslutningstagen over livscyklussen. Denne artikel er i øjeblikket genindsendt til det akademiske tidsskrift *Management Science*. Ved brug af et unikt datasæt med detaljerede oplysninger om danske husholdninger og deres realkreditlån, viser vi at det er mere sandsynligt at unge og gamle husholdninger benytter afdragsfrie lån sammenlignet med middel aldrende husholdninger. Unge husholdninger benytter afdragsfrihed fordi de forventer en højere fremtidig indkomst, gamle husholdninger fordi afdragsfrihed tillader dem at omgå en ellers bindende likviditetsbegrænsning. Gennem forskellige kanaler letter afdragsfrihed således forbrugsudjævning for unge og gamle husholdninger. Vores detaljerede data tillader os at undersøge hvordan husholdninger med afdragsfrie realkreditlån er forskellige fra husholdninger med realkredit uden afdragsfrihed med hensyn til gearing, gælds- og formuesammensætning, og pensionsbidrag.

Det andet kapitel, *The end is near: Consumption and saving decisions at the end of interest-only periods*, studerer husholdningers' forbrugs- og opsparingsadfærd i slutningen af afdragsfrie perioder, hvor amortisering påbegyndes eller en refinansiering finder sted. Ved hjælp af dansk registerbaseret data med detaljerede oplysninger om husholdninger med afdragsfrie realkreditlån, finder vi en positiv gennemsnitlig forbrugsrespons når en husholdning refinansierer til et nyt afdragsfrit realkreditlån, hvorimod den er negativ som følge af påbegyndelse af amortisering. For realkreditlån med udløbende afdragsfrie perioder dokumenterer vi en signifikant variation i forbrugsresponsen på tværs af alder og forbrugsniveau i den afdragsfrie periode, hvilket indikerer at forbrugsudjævning over realkreditlånets løbetid afhænger af disse karakteristika af låntagere. Unge låntagere benytter den ekstra likviditet i den afdragsfrie periode til at tilbagebetale bank gæld, hvorimod de andre låntagere primært har en tendens til at forbruge den ekstra likviditet. Ved udløb af den afdragsfrie periode ses en tendens til at nogle låntagere er tvunget til at påbegynde amortisering pga. lånebegrænsninger, som forhindrer dem i at omlægge til et nyt afdragsfrit realkreditlån, mens andre låntagere påbegynder afbetaling frivilligt for at minimere gældsomkostninger. Vores

resultater har betydning for regulering af afdragsfrie realkreditlån.

Det tredje kapitel, *Double Jeopardy: Households' consumption responses to shocks in stock and mortgage markets*, undersøger hvordan husholdningers' forbrug påvirkes af udfald i aktie- og realkreditmarkerne. Husholdninger nedjusterer forbrug efter nedgang i deres aktiebeholdning, som følge af kursfald. Ligeledes, reducerer husholdninger deres forbrug efter en eksogen stigning i deres realkreditydelser. Men hvad er virkninger af samtidige negative udfald på begge markeder, som f.eks. under finanskrisen i 2008? Ved brug af detaljerede danske husholdningsdata finder vi, at en forbrugsreduktion fordobles, hvis husholdninger er meget eksponeret over for både aktie- og realkreditmarkedet. Vi dokumenterer også, at de negative effekter varer ved over tid. Det har en voldsom effekt på forbruget da husholdninger med høj risikoprofil på aktiemarkedet også har en tendens til at have en høj eksponering i realkreditmarkedet. Vi diskuterer de underliggende årsager bag vores resultater og deres implikationer for makrotilsynspolitikker.

Contents

Introduction

The mortgage decision is typically the most important financial decision of a household, as housing often is the biggest household asset. Thus, mortgage choices regarding leverage, mortgage type, mortgage rate type, etc. are essential for the wealth and welfare of the household, in the present as well as in the future. In this PhD thesis, I study how the household's mortgage choice affects its other financial decisions regarding consumption, investment, pension savings, and other savings. In particular, I investigate how the introduction of non-conventional interest-only (IO) mortgages affects household consumption and savings. The three chapters of this PhD thesis consist of three independent research papers that can be read separately. All papers are placed within the field of Household Finance.

For the research projects, we use a unique panel data on mortgages combined with Danish register-based data on property data, socioeconomic data, and demographical data. Danish register-based data covers all Danish tax-liable individuals, and it is maintained and administrated by Statistic Denmark. From 2009 to 2018, we have access to mortgage data on approximately 94% of all Danish mortgage holders. The mortgage data is also made available through Statistic Denmark, which obtains the data from the Association of Danish Mortgage Banks (Realkreditrådet) and the Danish Mortgage Banks' Federation (Realkreditforeningen). In addition, we also have access to mortgage data from 2001 to 2008, provided by one of the largest mortgage banks in Denmark. The time span of our data covers both the introduction of the IO mortgages in 2003, as well as the eruption of the financial crisis in 2007. As the IO period is limited to 10 years in Denmark, our data also spans over households with expiring IO mortgages.[1] Thus, the richness of our data allows us to study consumption and savings behavior around the introduction of IO mortgages and at the expiration of IO periods, as well as the consumption effect of risk exposure to the mortgage market, when both the mortgage and stock market are simultaneously hit by a shock in the financial crisis in 2008.

The first chapter is a paper co-authored with Linda Sandris Larsen, Claus Munk, and Jesper Rangvid. In light of the heavy criticism of IO mortgages and other non-conventional loans in

[1] Since 2017, mortgage banks have offered borrowers with an LTV below 60% a new type of IO mortgages with no repayments until maturity at 30 years. This new IO mortgage, introduced at the very end of our sample, is thus unlikely to affect our data.

the debate following the financial crisis that erupted in 2007, we study *which* households use IO mortgages, and *how* households use IO mortgages in conjunction with their consumption and investment decisions over the life cycle. We find that both young and old households are more likely to use IO mortgages compared to middle-aged households. Examining consumption behavior over the life cycle across mortgage choice, we document that young and old households with IO mortgages are net-borrowers i.e., consume more than income on annual basis, on average. On the other hand, middle-aged households with IO mortgages and household with repayment mortgages are net-savers. Thus, this pattern indicates that the financial flexibility offered by IO mortgages facilitates consumption smoothing over the life cycle.

We provide new evidence explaining why old households choose IO mortgages. After retirement, households with low pension and little other income may find IO mortgages beneficial in order to sustain their consumption level. Especially for liquidity-constrained households with high housing wealth, where continued mortgage amortization is suboptimal, this is true. Using a difference-in-difference approach, we document that the introduction of IO mortgages in Denmark in 2003 led to approximately 8% higher annual consumption of liquidity-constrained, near-retirement households compared to similar unconstrained households. Hence, the access to IO mortgages has significantly improved the welfare of constrained older households.

For young households, we document that the household's expected income growth increases the likelihood of having an IO mortgage. This is consistent with findings in existing literature. Thus, young household expecting a higher income in the future, are more likely to use the financial flexibility offered by IO mortgages to postpone mortgage amortization to the future, where higher income is expected. Regarding households' investment, savings and debt decisions, we show that households with IO mortgages are more indebted, but pay down non-mortgage debt to a larger extent, save more in stocks, and contribute more to pension savings, compared to households with repayment mortgages.

Overall, our findings suggest that IO mortgages facilitate consumption smoothing, and allow households to reduce life-cycle borrowing costs and to improve asset portfolio diversification - all of which benefit the overall welfare of the households. Contrarily, these welfare benefits can be contrasted with the higher leverage of households with IO mortgages.

The second chapter also investigates how IO mortgages affect consumption and saving decisions, but instead of exploring consumption and saving patterns of IO borrowers at mortgage origination, we investigate consumption and saving behavior at the end of IO periods, where amortization starts or a new IO mortgage is originated. Consumption and savings behavior around the end of the IO period is important for regulation of IO mortgages as it addresses central issues related to the use of IO mortgages, such as whether IO borrowers manage to plan consumption and savings during the IO period to maintain consumption after amortization starts, and how the leverage of

IO borrowers changes when they rollover their IO mortgage to a new one.

We show that refinancing in Denmark is common. Thus, many IO borrowers refinance the IO mortgage before the IO period expires. We find that the average IO borrower that refinance to a repayment mortgage consumes the same before and after refinancing, and only increases debt a bit in the refinancing year. Results thus indicate that the IO borrowers that refinance to a repayment mortgage manage to start amortization without reducing consumption, suggesting that they are better off after refinancing. In contrast, we show that the IO borrowers that refinance to a new IO mortgage consume the same or more after refinancing, on average. On top of that, they tend to increase mortgage debt in the refinancing year. In the short run, IO borrowers that refinance to a new IO mortgage thus seem to be better off, but over a longer perspective, this may not be the case. We argue that the tendency to take on more debt when refinancing to a new IO mortgage is worrying as future IO borrowers then are more indebted and thus more likely to end in financial difficulties in the future, everything else equal. However, the financial situation of a household changes with, for example, house prices and interest rates. To evaluate the financial situation of IO borrowers that refinance to a new IO mortgage, we therefore need to track the second round of IO periods. Unfortunately, this is not possible within the time span of our data.

For rational unconstrained IO borrowers that start amortization early or at the expiration of the IO period, we expect borrowers to consume the same before and after amortization starts. For IO borrowers that start amortization early, the decision to start amortization early is voluntary, and thus no consumption response to the increase in mortgage payments is expected. For IO borrowers that let the IO period expire, the amortization period is planned. As predicted by the permanent income hypothesis, the anticipated reduction in disposable income when amortization starts should not affect the consumption of rational unconstrained borrowers. Against expectations, we document a negative consumption response to the decrease in disposable income when the IO period expires, indicating that the average IO borrower fails to smooth consumption over the mortgage life. This is consistent with findings in existing literature. By examining the cross-sectional variation in the consumption behavior across borrower characteristics, we show that age and average consumption to lagged income (CTI) during the IO period are key determinants of the consumption behavior around expiration of the IO period. More specifically, when mortgage payments increase by 8%-9% of income, young IO borrowers reduce consumption by approximately 3% of income, whereas middle-aged and older IO borrowers reduce consumption by approximately 6% of income. Across quartiles of average CTI during the IO period, we show that when mortgage payments increase by approximately 7%-11% of income, the average IO borrower within quartile 1 increases consumption by approximately 14%, whereas the average IO borrower within quartile 2, 3, and 4 reduces consumption by approximately 3%, 9%, and 17% of income, respectively.

The two determinants are correlated, in the sense that the different age groups use the extra

liquidity during the IO period for different saving and consumption purposes. The average young borrower uses saved repayment to repay bank debt during the IO period, whereas the average older borrower uses them for consumption. Middle-aged households' use of saved repayments tend to driven by a mixture of the two but on a lower scale. The age-differences in the usage of extra liquidity in the IO period explain the variation in consumption behavior across age groups.

Starting amortization at expiration may be a voluntary of forced decision. We find evidence in favor of both. IO borrowers may have incentive to start amortization to build up home equity, avoid future borrowing constraints, or to reduce the cost of debt. The last mentioned seems to be the case for young IO borrowers. We find evidence suggesting that young IO borrowers use the IO mortgage as part of a repayment plan that minimizes the cost of debt over the life cycle, while keeping debt payments stable. On the top of that, young IO borrowers and IO borrowers with lower average CTI during the IO period are more likely to start amortization (either by keeping the IO mortgage and start amortization or by refinancing to a repayment mortgage). Thus, results imply that young IO borrowers voluntary start amortization. Evidence on loan to value for middle-aged and older IO borrowers suggests that some IO borrowers voluntarily start amortization at expiration to lower the contribution fee and thereby the cost of debt. More specifically, we find that loan to value (LTV) hovers around 60% for middle-aged IO borrowers that refinance to a new IO mortgage and around 40% for older IO borrowers that refinance to a new IO mortgage, whereas LTV for other middle-aged and old IO borrowers generally is higher. Results imply that IO borrowers with LTV reaching one of the two cutoff points (40% and 60%), of which contribution fees are lowered, choose to refinance to a new IO mortgages, whereas the others start amortization. Additionally, however, a higher fraction of borrowers that start amortization at expiration have a loan to value higher than 80%, which indicates that borrowers are borrowing constrained and cannot be granted a new IO mortgage upon expiration.

Our findings suggest several possible changes of regulation on IO mortgages. For young borrowers, the granting process could optimally depend on whether they want to use saved repayments during the IO period to repay bank debt. For middle-aged and older borrowers, our findings points to the fact that regulation may be needed for borrower with low home equity, whereas it is not needed for borrowers with high home equity. Softer regulation may also be sufficient; (1) banks could increase borrowers' awareness of possible future borrowing constraints to ensure that constrained borrowers do not plan to roll-over to a new IO mortgage when IO period expires, or (2) banks could help borrowers to commit themselves to increase bank holdings or other liquid holdings during the IO period to cover increased mortgage payments after the IO period.

The third chapter is written in collaboration with Linda Sandris Larsen, Ulf Nielsson, and Jesper Rangvid. The paper examines how a household's exposure to the stock and mortgage market affect consumption of the household. During the peak of the financial crisis in the end of

2008, the mortgage and the stock market were simultaneously hit by negative shocks. Existing literature tests the consumption effect of either stock market changes or mortgage market changes separately. But in events like the financial crisis, it is essential to find out how the economic situation of households investing in both markets is affected; is the total consumption effect equal to the sum of the consumption effect of asset exposure and liability exposure, is there a diversification effect that softens the total impact, or is the total impact magnified?

By exploiting cross-sectional variation across households' risk attitudes towards mortgage and stock markets, we show that households highly exposed to both the stock and the mortgage market decrease consumption by 100% more compared to those only highly exposed to one of the markets. In more detail, we find that households, who are highly exposed to either the mortgage or the stock market, but not both, reduce consumption by 10% in 2008, whereas households who are highly exposed to both markets cut consumption by approximately 20%, compared to households having a low exposure to both markets. Thus, the total consumption effect equals the sum of the consumption effect of the asset exposure and the liability exposure.

We show that the consumption effect of the negative economic shock in 2008 is persistent, but with a diminishing effect. We find that households highly exposed to the stock market tend to stop investing in risky assets after being hit by the negative economic shock in 2008. Strikingly, however, the exit rate is higher for households who are highly exposed to the mortgage market at the same time. Households with relatively few liquid assets before the crisis mainly drive the higher exit rate among households highly exposed to both market. We argue that this reflects a learning pattern or a need for liquidity, i.e., households sell risky assets to reduce overall risk or to release liquid assets to cover mortgage payments. Additionally, we investigate correlations between household's risk exposure in the stock and in the mortgage market, just prior to the negative economic shock. We find a positive correlation, i.e., households with a high-risk profile with respect to the mortgage market tend to hold a high share of risky assets. We apply several proxies of risk attitude towards liability, e.g., mortgage payment-to-income, the ratio of debt to assets, the mortgage interest type (adjustable or fixed), and the mortgage type (IO mortgage or repayment mortgage), whereas we use the share of risky assets to measure risk attitude towards assets. For all proxies of risk attitude towards liability, we document a positive correlation. These findings highlight the importance of accounting for households' exposure to both markets and not only one.

Thanks for reading.

Chapter 1

How do Interest-only Mortgages Affect Consumption and Saving over the Life Cycle?

How do Interest-only Mortgages Affect Consumption and Saving over the Life Cycle?

Linda Sandris Larsen Claus Munk Rikke Sejer Nielsen Jesper Rangvid

October 29, 2021

Abstract

Using a unique data set with detailed information on Danish households and their mortgages, we show that young and old households are more likely to use IO mortgages compared to middle-aged households. Young households use IO mortgages because they expect higher future income, old households because IO mortgages allow them to circumvent an otherwise binding liquidity constraint. Through different channels, IO mortgages thus facilitate consumption smoothing for young and old households. Our detailed data also allow us to examine how households with IO mortgages differ from households with repayment mortgages in terms of leverage, debt and asset composition, and pension contributions.

Keywords: Interest-only mortgages; micro data; consumption and savings pattern; life-cycle planning; financial constraints

JEL subject codes: G11

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1 Introduction

Interest-only (IO) mortgages and other non-conventional loans were—together with lenders' lax underwriting standards—heavily criticized in the debate following the financial crisis that erupted in 2007.[1] Mortgages with no or even negative amortization were issued on a large scale in 2004–2006 in the US and many other countries. When home prices subsequently plummeted, many homeowners went underwater and default rates spiked with severe macroeconomic ramifications. Due to their importance for financial stability and households' life-cycle planning, a substantial literature on IO mortgages has emerged, examining who use them (Cocco, 2013; Cox, Brounen, and Neuteboom, 2015; Gathergood and Weber, 2017; Amromin, Huang, Sialm, and Zhong, 2018), how IO mortgages impact financial stability (Campbell, Clara, and Cocco, 2021), whether IO mortgages lure households into excessive leverage and consumption (Laibson (1997) and references in footnote 1), and whether IO mortgages help facilitating rational households' life-cycle planning by offering greater financial flexibility (Cocco, 2013). In spite of significant progress in our understanding of households' use of IO mortgages, important gaps remain. In particular, it is not fully clear *which* households use IO mortgages, and *how* households use IO mortgages in conjunction with their consumption and investment decisions over the life cycle. For the debate about the benefits versus costs of IO mortgages, it is obviously important to know how IO mortgages are used by households. This paper makes progress on these questions using a comprehensive register-based panel data set from Denmark.

The time-span of our data allows us to take a life-cycle perspective on how IO mortgages are used. We find that both young and old households are more likely to use IO mortgages compared to middle-aged homeowners, also after controlling for differences in, e.g., income, education, and debt-to-assets. Interestingly, we find that young and old households with an IO mortgage consume more than current income, whereas the reverse is true for middle-aged household. Hence, young and old households with an IO mortgage are net-borrowers, whereas middle-aged homeowners with an IO mortgage are net-savers. This pattern indicates consumption smoothing over the life cycle. On the other hand, homeowners with a repayment mortgage are net-savers over the entire life-cycle.

We provide new evidence explaining why old households choose IO mortgages. Retirees receiving a low pension and little other income might want to reduce net wealth in order to sustain

[1] See, e.g., Baily, Litan, and Johnson (2008), Mayer, Pence, and Sherlund (2009), Bernanke (2010), Acharya, Richardson, van Nieuwerburgh, and White (2011), Demyanyk and van Hemert (2011), and United States Senate (2011).

their consumption level, and thus continued saving through mortgage amortization is suboptimal.[2] This motivation applies in particular to liquidity-constrained retired homeowners for whom the home equity is the dominant part of their net wealth. An IO mortgage allows such homeowners to stay in their home and at the same time maintain a reasonable level of consumption. Thereby, they avoid a potentially stressful and costly process of selling and moving, which is the ultimate alternative way of liquefying housing wealth. In a difference-in-difference estimation, we show that the introduction of IO mortgages in Denmark in 2003 led to approximately 8% higher annual consumption of liquidity-constrained, near-retirement households compared to similar unconstrained households. Hence, the access to IO mortgages has significantly improved the welfare of constrained older households. We argue and test that these positive effects do not arise because of a general credit-supply shock to the economy, but are due to the greater financial flexibility that IO mortgages provide.

Consistent with the life-cycle consumption smoothing motive, we show that the likelihood of a young household having an IO mortgage increases considerably with the household's expected income growth. This observation is in accordance with the main finding of Cocco (2013) who documents a positive relation between income growth and IO mortgages in a sample of UK households of age 20-60. We refine his conclusion by showing that the relation is strongly positive for young households but decreases with age and turns negative so that among older households IO mortgages are taken more frequently by households expecting lower income growth.[3]

How do households use the extra liquidity that IO mortgages temporarily provide for? Borrowers may potentially use IO mortgages to take a larger mortgage and buy a more expensive home. But this is not all. Recent papers based on US data study the relation between mortgage-payment reductions and consumption/saving decisions, see Di Maggio, Kermani, Keys, Piskorski, Ramcharan, Seru, and Yao (2017), Agarwal, Amromin, Chomsisengphet, Landvoigt, Piskorski, Seru, and Yao (2017), and Abel and Fuster (2021). They show that the reduction in mortgage payments leads to lower mortgage default rates, increases in car purchases—measured using auto loans—as well as increases in voluntary mortgage repayments. These findings advance our understanding of how IO mortgages influence parts of households' consumption (car purchases) and parts of their debt (mortgage debt), but they do not address the broader questions of whether households with IO mortgages increase their overall total consumption, total debt, and total savings, and how IO

[2] A reverse mortgage may be an alternative to an IO mortgage, but reverse mortgages are not standard products in the Danish market.

[3] We have data on both labor income and consumption, whereas Cocco (2013) only has income data. While Cocco (2013) considers a sample combining all households of age 20-60, we study the relation between mortgage choice, income, and consumption across nine age groups that also include households of age 60 and above, which gives additional insights into life-cycle patterns.

mortgages influence the composition of total debt and savings. Using our comprehensive data, we can do so.

We show that, at any age level, households with IO mortgages tend to have a larger total debt, a larger debt-to-asset ratio, a larger loan-to-income ratio, as well as a larger consumption-to-income ratio than households with repayment mortgages. But we go further than this. We use our rich data on Danish households to provide a more detailed picture of how IO mortgages correlate with debt and savings. First, access to IO mortgages can reduce life-time borrowing costs since IO borrowers can pay down other, more expensive, debt earlier. Indeed, IO borrowers above age 40 have a smaller fraction of their debt as non-mortgage debt than borrowers with repayment mortgages. Secondly, we document how mortgage choice is related to stock and bond investments. For example, the stock market participation rate for middle-aged and old households is about five percentage points higher among IO borrowers than among borrowers with an amortizing mortgage. Interestingly, among young households the stock market participation rate is lower for IO borrowers. Hence, if stock market participation reflects risk tolerance, our results question the conclusion of Cox et al. (2015) that risk tolerance is a key driver of mortgage choice. We also find that among homeowners older than 50 years, IO borrowers make larger contributions to private pension plans which indicates that households might exploit a tax-arbitrage opportunity by reducing mortgage repayments and increasing pension contributions, consistent with the idea of Amromin, Huang, and Sialm (2007).[4] Overall, we find that IO borrowers replace, at least to some extent, the reduced savings in real estate by investments in other assets, leading to a better diversified asset portfolio.[5] Notably, in our sample, these benefits of IO mortgages are not counterbalanced by larger financial difficulties during downturns. In spite of higher debt levels, debt-to-asset ratio, and loan-to-income ratio, IO borrowers in our sample did not default with a significantly higher frequency than repayment borrowers during the financial crisis.

Households choose the type of their mortgage jointly with consumption and investment decisions, including the decision to purchase a house. The correlations between mortgage type and household characteristics we identify are consistent with the view that many households include the IO/repayment choice in their overall life-cycle decision problem in a rational way. Of course, both the IO/repayment choice and the decisions regarding house purchases, consumption, saving,

[4]Institutional differences between the Danish and US tax and pension systems imply that the tax-arbitrage strategy in a Danish setting is somewhat different from that suggested by Amromin et al. (2007) and only available to some households close to retirement, cf. the discussion in Section 4.3.

[5]In addition to these effects, a young household may purchase its long-term preferred residence right away by using an IO mortgage, instead of a smaller starter home with subsequent steps up the housing ladder. This could reduce total housing transactions costs over the life cycle. However, given the time span of our data, we cannot detect significant differences in the transaction frequency of IO borrowers compared to borrowers choosing conventional mortgages.

and financial asset holdings can be affected by unobservable variables, such as the underlying preferences of the household. IO mortgages (in particular those with an adjustable rate) seem more risky than repayment mortgages (in particular those with a fixed rate), which suggests that more risk-tolerant households would tend to choose IO mortgages. At the same time, they would, among other things, tend to save less and investment more in stocks. On the other hand, an adjustable-rate IO may be the rational choice also for risk-averse households facing a labor income which is relatively risky and positively correlated with the adjustable mortgage rate, so that the household typically pays only a low interest rate should their income drop. As mentioned above, the relation we identify between mortgage type and stock market participation questions the hypothesis that risk aversion drives the IO/repayment choice. Numerous studies find that individuals' risk aversion increases with age (Bakshi and Chen, 1994; Albert and Duffy, 2012) but, if this is so, our overall finding that IO take-up is U-shaped in age also questions the view that risk aversion is a main determinant of mortgage type.

To sum up, we offer a number of contributions relative to the current literature on IO mortgages. First, other papers do not take the life-cycle perspective we do. Our paper, thus, offers a richer description of how young, middle-aged, and old households use IO mortgages. Our finding that older households benefit from access to IO mortgages, as they relax an otherwise binding liquidity constraint, is particularly noteworthy. Furthermore, we are able to study how IO mortgages influence other financial decisions of households (stock market investments, pension contributions, etc.), something that is difficult to do without comprehensive data on household portfolios over the life cycle.

There are considerable challenges involved in conducting an empirical analysis of which and how households use IO mortgages. First, one must have data for a large representative sample of households who use IO mortgages and a sample using repayment mortgages, such that the two groups can be contrasted. Second, for both groups, one needs data that allow for a calculation of consumption and savings at the household level. Third, to say something meaningful about saving decisions, information about the composition of households' portfolios is required, i.e., their holdings of bonds, stocks, etc. Finally, one needs exogenous variation in the availability of IO mortgages. With few exceptions, previous research has studied IO mortgages and other alternative mortgage products using US or UK data. US data sets are typically not including both households using IO mortgages and households using repayment mortgages, and lack detailed information about portfolio composition at the household level. Moreover, exogenous variation in the access to alternative mortgage products is typically unavailable.

To overcome these challenges, we use a comprehensive register-based panel data set from Denmark with detailed information on the mortgages of more than 400,000 households in the period 2001–2015 coupled with register-based data on, e.g., household wealth and income from which we can infer the household's consumption. The Danish mortgage system is renowned for its long-proven stability, efficiency, and transparency, cf. Campbell (2013) and Section 2 below. While sharing many features of the US market, the Danish mortgage market was less affected by the financial crisis, and the share of IO mortgages has remained high in Denmark. Importantly, our data span the sudden, exogenous introduction of IO mortgages in Denmark in 2003, allowing us to address the question of causality from IO mortgages to consumption and saving decisions. Furthermore, we have comprehensive data on users of IO mortgages and repayment mortgages, as well as information about the financial portfolios of households. Finally, we have information about income, education, geographical location, etc., that allows us to control for confounding effects when investigating life-cycle patterns in saving-consumption decisions of households with different mortgage types.

In addition to the literature already mentioned, a number of papers examine related aspects of households' mortgage decisions. Several papers investigate the choice between an FRM (fixed-rate mortgage) and an ARM (adjustable-rate mortgage) in life-cycle models (Campbell and Cocco, 2003; Koijen, van Hemert, and van Nieuwerburgh, 2009; van Hemert, 2010), while ignoring the IO/repayment decision. In a more simplistic modeling framework, Chiang and Sa-Aadu (2014) study mortgage choice with a menu of contracts including the pay-option ARM that can be seen as a combination of an IO mortgage and an equity line of credit. In a stylized dynamic contracting model, Piskorski and Tchistyi (2010) find that the optimal mortgage contract resembles such an option ARM, and that the gains from taking the non-conventional optimal mortgage are largest for homeowners who face more volatile income, buy more expensive homes given their income level, and who make no or a small down payment. Koijen et al. (2009) and Badarinza, Campbell, and Ramadorai (2018) show empirically that households' choice between FRMs and ARMs is affected by the FRM-ARM rate spread and expectations about future ARM rates. Andersen, Campbell, Meisner-Nielsen, and Ramadorai (2020c) study the 2009–2011 refinancing behavior of Danish households with a focus on how the refinancing activity varies with household characteristics such as age, educational level, income, and wealth.

Bäckman and Khorunzhina (2018) investigate the effect of IO mortgages on consumption and borrowing in Denmark, but do not address life-cycle patterns or the impact on households' other financial decisions. De Stefani and Moertel (2019) show how the Danish IO introduction affected

employment and workforce composition, whereas we focus on household-level consumption and savings. An IO mortgage might help a homeowner facing temporary financial hardship, as the homeowner can free up liquidity by refinancing from a repayment mortgage to an IO mortgage. Using Danish microdata, Andersen, Jensen, Johannesen, Kreiner, Leth-Petersen, and Sheridan (2020a) indeed find that individuals hit by unemployment shocks to a small degree increase their use of IO mortgages.[6]

Another line of research investigates the relation between house prices and household consumption, e.g. Campbell and Cocco (2007) using UK data, Mian, Rao, and Sufi (2013) and Kaplan, Mitman, and Violante (2020) using US data, and Browning, Gørtz, and Leth-Petersen (2013) using Danish data. An ongoing debate discusses whether the boom in house prices leading up to the Great Recession was primarily due to an increase in credit supply through relaxed lending standards (Mian and Sufi, 2017) or due to an increase in demand through households' expectations of future price changes (Adelino, Schoar, and Severino, 2016).

The remainder of the paper is organized as follows. Section 2 provides a short introduction to the Danish mortgage market, describes our data set and the key variables in our analysis, and presents summary statistics. Section 3 examines which types of households are more likely to use IO mortgages and how labor income and liquidity constraints influence households' decision to use IO mortgages. Section 4 documents how households with IO mortgages differ from households with repayment mortgages in terms of debt and asset composition and pension contributions. Finally, Section 5 concludes.

2 Data

2.1 Main data sources and features

In Denmark, residential mortgage loans are offered by specialized mortgage banks who act as intermediaries between households and investors. We have detailed data on more than 980,000 loans issued by a major mortgage bank during the period 2001–2015. The name of the bank must be kept anonymous, but it has a market share of over 20% of the Danish mortgage market and lends out in all geographic areas of Denmark and to all types of customers. The data contain the personal identification number of borrowers and mortgage characteristics such as a unique mortgage identification number, the loan amount, the time to maturity, and the mortgage type specifying whether the mortgage includes a repayment commitment or not, and whether the interest rate

[6]The modest effect found in Andersen et al. (2020a) is consistent with Defusco and Mondragon (2020) showing that an unemployed has a high demand for mortgage refinancing, but is constrained by the unemployment status.

is fixed or adjustable. The time span of the data set covers both the financial crisis and the introduction of IO mortgages in 2003. A related data set covering all Danish mortgage banks from 2009 and onwards is made available by Finance Denmark (an interest organization for financial institutions) and Danmarks Nationalbank (the central bank of Denmark) and is accessed through Statistics Denmark; this is the data used by Andersen et al. (2020c) and others. That data set does not cover the introduction of IO mortgages in 2003 as well as the financial crisis in 2008 used as exogenous shocks in our study. However, we use the larger post-2009 data set in case a given household changes mortgage bank after 2009 allowing us to follow the given household for a longer period.[7]

Given the borrowers' personal identification number, Statistics Denmark supplies a number of relevant socioeconomic variables such as the educational history and, on an annual basis, the labor income, bank debt and deposits, holdings of stocks and bonds, as well as contributions paid to pension saving schemes. We have this information for all households in Denmark in the full period from 2001–2015.

2.2 The Danish mortgage market

Before going into details of the data set and what we do with it, we provide a short description of the Danish mortgage system. For more information, see, e.g., Gyntelberg, Kjeldsen, Nielsen, and Persson (2011) and Danske Bank (2017). The Danish mortgage system dates back to 1797 and has been regulated by law since 1850 with the key objective of providing homeowners with inexpensive low-risk funding. Mortgage banks form large pools of geographically diversified mortgages having identical terms (different loan sizes, though) and then issue a series of identical covered bonds receiving payments that closely match the incoming payments from borrowers on the mortgages in the pool. While the interest rate paid on the mortgage matches the coupon rate of the associated bond, borrowers have to make additional contribution payments proportional to their outstanding debt to cover the mortgage bank's expenses and maintain its reserves.[8] Together with relatively strict regulation, an 80% maximum residential loan-to-value ratio, and conservative underwriting standards, the system has exhibited a remarkable stability even through financial crises and thus received considerable international attention (Campbell, 2013). When a borrower defaults on a mortgage, the corresponding bonds are paid out of the reserves of the issuing mortgage bank, and

[7] Danish households are very loyal to their mortgage bank. In the 2004-2015 period only about 3% of all households changed mortgage bank per year (Danish Competition and Consumer Authority, 2017).

[8] Until 2011 the contribution rate was around 0.5% for all mortgage types. Since then the mortgage institutions have increased contribution rates on loans with IO, ARM, and high loan-to-value (LTV).

not a single bond default has been recorded in the more than 220-year long history of the system.

Danish mortgage-backed bonds are listed on the Nasdaq Nordic Exchange and most bond series trade with a fair or excellent liquidity (Dick-Nielsen and Gyntelberg, 2020). In June 2017 the face value of all outstanding Danish mortgage-backed bonds (residential and commercial) totaled around DKK 3,000bn (EUR 400bn, USD 450bn) making it the largest European covered bond market. The bonds receive top ratings from international credit rating agencies, and as of April 2017 foreign investors hold 24% of the bonds whereas 69% are owned by Danish financial institutions, insurance companies, and pension and mutual funds (Danske Bank, 2017).

As in the US, the predominant mortgage in Denmark has traditionally been a 30-year annuity-style FRM with a penalty-free prepayment option. However, all Danish mortgages are recourse loans, allowing the borrower to settle his debt by delivering corresponding bonds purchased at market value to the issuing mortgage bank, and can be taken over by the new owner when the underlying property is sold. ARMs were introduced in Denmark in 1996 and are offered with various rate reset frequencies.

IO mortgages were introduced in Denmark in 2003 and several observations indicate that the introduction can be seen as an exogenous shock. First, the law introducing IOs was passed relatively fast. Discussions about introducing IOs started in the Danish financial sector in late 2002, the bill was first discussed in parliament in Spring 2003 and eventually passed on June 1st, and IO mortgages became available from October 1st, 2003. Second, and most important, if the introduction of IOs had not been exogenous but expected, we should not have seen any effect on house prices. However, house prices increased markedly after the 2003 IO introduction, cf. Figure 4. Dam, Hvolbøl, Pedersen, Sørensen, and Thamsborg (2011) estimate the independent effect of IOs on Danish house prices and find that house prices would have been 15-20% lower at their peak in 2007, had IOs not been introduced in 2003.[9] This large price effect implies that the introduction of IOs in 2003 was an unexpected shock to the Danish housing market.

An IO mortgage gives the borrower up to 10 years in which no repayment of debt has to be made so that only interest payments (and the above-mentioned contributions) are needed. Some mortgage banks require that the interest-only period is a continuous period starting at the initiation of the loan, whereas others grant the borrower the option to select shorter interest-only periods (totaling at most 10 years) along the way. The vast majority of IO mortgages, however, are issued with a 30-year maturity and have only interest payments in the first 10 years. Whether the IO period is a continuous 10-year period or consists of shorter IO periods, the loan has to be

[9] Also, in a US context Barlevy and Fisher (2021) show that the share of IOs is tightly correlated with the rate of house price growth in a city even after controlling for other mortgage characteristics.

paid back within the full 30-year period. For this reason, the interest rate on an IO mortgage is not significantly different from the interest rate on a repayment mortgage. Given the embedded penalty-free prepayment option (subject to transaction costs, though), a borrower might decide to refinance into a new IO mortgage after the end of the 10-year IO period—and thus extending the IO period—provided that the loan-to-value ratio of the new loan is still below the 80% limit. Both FRMs and ARMs can have an IO feature so four main mortgage types exist: IO-FRMs, repayment FRMs, IO-ARMs, and repayment ARMs.

Regulation stipulates that mortgage banks are only allowed to grant a mortgage with an interest-only period or an adjustable rate or both if the borrower can afford a conventional 30-year FRM.[10] Based on the learnings from the financial crisis, the Danish FSA in December 2014 introduced the so-called Supervisory Diamond for mortgage banks. The Supervisory Diamond sets a number of benchmarks with associated limits for when a Danish mortgage bank is considered to be too risky in its lending. One limit restricts the amount of IO mortgages a mortgage bank can issue. This change in regulation happens at the very end of our sample period and is thus unlikely to affect our results.

Figure 1 shows that the share of IO mortgages started out around 14% in 2004, hit 40% in 2007 and 50% in 2009, and peaked at 56% in 2012–2013 after which it dropped to 52% in December 2015. In that month approximately 23% of the IO loans were issued with a fixed rate, 77% with an adjustable rate. Figure 1 also shows that the nominal value of outstanding FRMs has remained fairly stable in the 2003–2015 period, whereas the ARM market has grown substantially from around 30% of all mortgages in 2003 to 63% in 2015, a small decline from the 67-68% peak in 2012–2013.

[Figure 1 about here.]

Figure 2 depicts the average short-term and long-term yields on Danish mortgage-backed bonds over the period 2000–2014. The interest rates on ARMs [FRMs] typically follow the short-term [long-term] bond yields. Yields fell before the financial crisis, rose during it, and have fallen substantially since 2009 with short-term yields even turning negative in 2015. The increased gap between the long and short rate affects the incentive to choose ARMs over FRMs, and may also indirectly affect the incentives to choose an IO over a repayment mortgage, and hence explain the increased interest of IO mortgages with an adjustable rate. As discussed by Foà, Gambacorta, Guiso, and Mistrulli (2019), lenders could have incentives to supply more of one type of mortgage than other types. However, in the main part of the time-span in our study, the fees banks earn

[10] §4, Chapter 2, in the Law for mortgage loans and mortgage bonds etc.

on different types of mortgages are flat and equal across different mortgage types (The Danish Ministry of Industry, Business, and Financial Affairs, 2016, Figure C), so we do not believe that the mortgage banks preferred issuing IO mortgages instead of repayment mortgages.

[Figure 2 about here.]

Figure 3 shows that the homeownership rate has been stable from 2001 to 2015 in most age groups. However, the homeownership rate has decreased for the very young households which might be due to increasing house prices making it more difficult to enter the housing market. In contrast, the homeownership rate has increased for the oldest households which could be related to the introduction of IO mortgages.

[Figure 3 about here.]

Finally, as additional background information, Figure 4 illustrates how house and apartment prices have developed across the five regions of Denmark from 2001 to 2016. All regions experienced a significant increase in prices from 2001 up to around 2007 after which prices generally declined. In 2012, prices started increasing again, with a substantial recent increase especially for apartments. Home prices are highest in the Copenhagen area: in 2016Q4 the average price per square meter for one-family houses was DKK 22,900 in Copenhagen and DKK 8,700-11,100 in the other four regions and for apartments DKK 30,900 in Copenhagen and DKK 14,200-20,600 in the other regions. The figure shows a clear difference in the price development across the five regions which we will control for in our regressions.

[Figure 4 about here.]

2.3 Details of our data set

In our data from a major mortgage bank we focus on the 86.9% of mortgages issued on residential property and thus exclude commercial mortgage loans. We exclude the mortgages issued before 1970 (only 0.5% of all mortgages) because of a major change in mortgage regulation that year which, among other things, reduced the maximum loan-to-value ratio and the maximum maturity.

We link individual mortgages to the household characteristics of borrowers. We define a household as one or two adults living at the same postal address. In cases where only one of the adults in the household holds the mortgage, we also include the second adult's contribution to general

economic variables such as income, debt holding, stock holdings, etc., but omit the contribution from children in the household unless they are registered as one of the borrowers of the mortgage.

Almost 30% of the households have more than one mortgage; the average is 1.2 mortgages per household. To obtain a direct link between mortgage choice and household characteristics we use only one mortgage per household. This *dominant mortgage* is the mortgage with the highest loan amount. If the household has several mortgages with the same loan amount, the dominant mortgage is defined as the one with the highest outstanding debt. Households sharing mortgages with other households are excluded (e.g. divorced couples still owning a house together) to avoid having special family arrangements influencing the results. In total and after exclusions, we have data on 983,822 mortgages issued to 733,222 individuals in 443,600 households over the period 2001–2015.

2.4 Key variables in our analysis

2.4.1 Mortgage-specific variables

The *household loan amount (outstanding debt)* is the total loan amount (outstanding debt) of all mortgages held by the household. *LTI* is the ratio of the loan amount to the annual household income. The *nominal interest rate* is the nominal rate paid on the dominant mortgage and is presented in percent. *FRM* takes a value of 1 for a fixed-rate mortgage and 0 for an adjustable-rate mortgage. Likewise, *IO mortgage* takes a value of 1 for an IO mortgage, i.e. a mortgage without a required repayment in the year in question, and 0 for a mortgage with a mandatory repayment. The *actual IO period* takes a value of 1 if no repayment on the loan is made at the given point in time, either by default or because the borrower exercises an option not to repay. Finally, the variable *at least one IO mortgage* is a dummy variable for households having at least one IO mortgage.

2.4.2 Household-specific variables

The *age* of the household is defined as the average age of the borrowers of the mortgage. From Statistics Denmark we have annual observations of various financial variables of each individual, which we aggregate to the household level. *Household total debt* is the sum of the mortgage debt, bank debt, and all other types of debt registered for the household. *Household income* is the disposable income of the household defined as its total income less interest payments and tax payments. Total income consists of labor income, social welfare, unemployment benefits, child benefits, pension payouts, capital income, and inheritance. The *debt to asset ratio* is defined as

total debt over total assets, where the latter includes cash, stock and bond holdings, as well as the public property value of all properties owned by the household.[11]

Statistics Denmark reports for each individual an *education level* from 1 to 4. Level 1 represents primary school or less, level 2 secondary school or vocational education, level 3 is short-, medium-, or long-term higher education, and level 4 means PhD or similar. We include the relatively few individuals with level 4 education in level 3 in our analysis. The *education level* of the household is defined as the highest education level in the household. *Household type* corresponds to either 'Single,' 'Couple,' or 'Several families' where in the latter case the household's adults belong to different families. The geographical dimension is represented by which of the five administrative regions of Denmark (*Copenhagen, Zealand, Southern Denmark, Central Jutland, Northern Jutland*) the property is located in. When analysing regressions involving consumption patterns we use regional trends in house prices instead of just regional and time dummies. Finally, the variable *Male* takes the value of 1 if the mortgage has a male borrower and 0 otherwise.

2.4.3 Consumption

We impute the household-level annual consumption from the income and wealth data supplied by Statistics Denmark, as done by Leth-Petersen (2010) and others.[12] Let c_t denote consumption and y_t disposable income in year t. Let A_t denote the value of the household's liquid assets (bank deposits including the balance of private pension schemes), M_t mortgage debt, and D_t bank debt and other debt at the end of year t. Based on the household budget constraint, total consumption is then imputed as

$$c_t = y_t - \Delta A_t + \Delta M_t + \Delta D_t, \tag{1}$$

where $\Delta A_t = A_t - A_{t-1}$ is the increase in liquid assets plus private pension contributions in year t, $\Delta M_t = M_t - M_{t-1}$ is the increase in mortgage debt, and $\Delta D_t = D_t - D_{t-1}$ the increase in bank

[11] The public property value is the tax authorities' assessment of the value of the property, based among other things on recent transaction prices in the neighborhood. The value is used for calculating the property taxes to be paid by the homeowner and is typically significantly lower than the potential market value of the property.

[12] The quality of this imputation is investigated by Browning and Leth-Petersen (2003). They compare data from a Danish Expenditure Survey to administrative data for the years around the survey and conclude that the imputed consumption measure gives a good match with households' self-reported total expenditures. Koijen, van Nieuwerburgh, and Vestman (2015) find substantial reporting errors in Swedish consumption survey data and argue for the use of imputed register-based consumption. Baker, Kueng, Meyer, and Pagel (2021) document a potential measurement error arising when retail investors buy and sell assets within a year as that moves imputed consumption. Since only a small proportion of Danish households invest on their own, this issue is unlikely to significantly affect our results.

debt and other debt.[13] The household's net savings in year t are $\Delta A_t - \Delta M_t - \Delta D_t$. Hence, consumption is simply income less net savings. Note that $\Delta M_t = 0$ for a household paying only interest on the mortgage, whereas $\Delta M_t < 0$ in case of a repayment mortgage. Therefore, an interest-only paying household must either consume more, increase assets, or reduce bank and other debt—or a combination hereof—compared to the case where the household has a repayment mortgage of the same size.

We do not include stock and bond holdings in the household's liquid assets. Including them would make imputed consumption of the (relatively few) households with significant positions excessively volatile in years with large movements in stock prices as seen around the financial crisis.[14] Another challenge is that the actual value of the home is unobservable between transactions. Consequently, in years where the household buys or sells real estate, the imputed consumption can severely misrepresent actual consumption as only the debt side is taken into account. For example, in a year where an individual sells a house worth DKK 1.5mn and buys another worth DKK 2.0mn and finances the difference by increasing the mortgage by DKK 0.5mn, this would show up on the right-hand side of Eq. (1) only as an increase in ΔM_t by DKK 0.5mn and thus consumption would appear to be DKK 0.5mn higher than otherwise. To avoid this issue, we disregard consumption in years where a housing transaction takes place. To control for differences in data registration of housing transactions, we disregard consumption in years where the total inflation-adjusted debt of the household increased or decreased by more than DKK 0.5mn in 2015-prices.[15] Following Browning and Leth-Petersen (2003), we exclude households with self-employed individuals due to their unstable income-tax conditions and the difficulties in measuring the value of their business.[16]

2.5 Summary statistics

Our data from the major mortgage bank provides a total of 2,664,423 household-year observations in the period 2001–2015. Table 1 presents the summary statistics with observations divided

[13] When calculating disposable income, voluntary private pension contributions are deducted from gross salaries). Pension contributions are considered as an increase in liquid assets and are thus included in ΔA_t.

[14] We cannot distinguish between changes in asset values due to active investment decisions of the household and changes due to unrealized gains and losses caused by market movements, where the latter might have little relation to consumption decisions. We find that consumption imputed without stock and bond holdings align well with survey-based consumption data, whereas imputed consumption calculated using stock and bond holdings are excessively volatile. These results are available upon request.

[15] Years of housing transactions count 5.1% of the observations, and large changes in total debt above DKK 0.5mn count 6.1%. In total, they represent 8.5% of the observations. Increasing the threshold defining a large change in total debt does not significantly change our results.

[16] We see no significant difference in the fraction of IO mortgages among households with at least one self-employed individual and the fraction of IO mortgages among households with no self-employed individuals in all the years from 2003 to 2015, cf. Table IA.3 in the Internet Appendix.

into subperiods or according to the mortgage type.[17] The observations are not equally distributed over the years as a result of an increase in the number of customers of the mortgage bank, so for the summary statistics for each mortgage type we represent each mortgage by a randomly chosen year to ensure that all mortgages are weighted equally. The summary statistics are similar for all Danish homeowners as for our sample, and we see no reason to believe that our sample is not representative of all Danish mortgage holders.[18]

[Table 1 about here.]

First, we describe the summary statistics for the different subperiods, cf. the shaded columns of Table 1. We focus on mortgage characteristics. The mortgage loan amount and outstanding debt as well as the household debt have increased substantially over the years, also when mortgage or total debt are measured relative to income or assets. For instance, the average loan-to-income ratio has increased from 2.24 in 2001-02 to 3.36 in 2011-15. Both household income and consumption have increased over time.[19] The consumption-to-income ratio is relatively stable around 1 over time.

The fraction of households in our sample for which the dominant loan is an IO mortgage has increased from 14% on average in 2003–06, to 35% in 2007–10, and 48% in 2011–15. In line with our observations for the overall Danish mortgage market, cf. Figure 1 discussed earlier, we see that 51% of the households in our sample in 2011–2015 have at least one IO mortgage. As previously mentioned, some of the IO mortgages do not require borrowers not to make repayments, but grants them the option not to do so. The summary statistics show that 93% of the IO mortgages only pay interest in the randomly chosen year for each mortgage. In other words, more than nine out of ten households with an IO mortgage use their right to pay only interest. As in the overall Danish mortgage market (see Figures 2 and 4), the popularity of FRMs in our sample has declined over the years with a corresponding growth in ARMs. The interest rates on the mortgages in our sample have decreased over the period considered both due to the general decrease in interest rates for all types of mortgages and to the increasing use of ARMs as these typically have lower interest rates than FRMs. Also note that for IO mortgages 33% are FRMs and 67% ARMs, whereas 68% of repayment mortgages are FRMs and only 32% ARMs. This difference explains why the average

[17] Table IA.1 in the Internet Appendix presents summary statistics separately for households with an IO mortgage and households with a repayment mortgage both over 2006–08 and 2009-11. The changes from the pre- to the post-crisis period are quite similar for the IO households and the repayment households.

[18] Table IA.2 in the Internet Appendix summarizes household characteristics for all Danish homeowners for the same four sub-periods as stated in Table 1.

[19] Income, consumption, debt, asset values, and pension contributions are in nominal terms. The annual inflation rate over the 2001-15 period has averaged 1.8%, peaking at 3.4% in 2008, and being as low as 0.5% in 2015. The average value of the consumer price index, CPI, is stated in the top of Table 1 with CPI=100 in 2015.

interest rate is higher for repayment mortgages than for IO mortgages. The average loan-to-income ratio (LTI) increases over the sample period. Looking at the average LTI by mortgage type, it follows that LTI equals 4.15 for the IO mortgages, whereas it is only 2.87 for the households with a repayment mortgage. This indicates that IO-borrowers borrow more and buy more expensive houses than borrowers with conventional repayment mortgages.

3 Which households use interest-only mortgages?

3.1 Mortgage choice across age groups

The summary statistics show a clear difference in mortgage choice across age groups. For example, households of age 34 or younger hold 21% of all IO mortgages but only 14% of all repayment mortgages. Households of age 65 or older also have a significantly larger share of all IO mortgages than of all repayment mortgages. In contrast, households of age 40-59 hold a larger share of repayment mortgages than IO mortgages. A similar picture emerges when looking at households entering the mortgage market in the 2004-2015 period. Figure IA.1 in the Internet Appendix shows that, among households entering the mortgage market, the fraction taking an IO mortgage is over 70% for households above 60, around 60% for households below 40, and only around 50% for the middle-aged households.[20] Figure IA.2 in the Internet Appendix shows that the fraction of households changing their dominant mortgage type (from IO to repayment or vice versa) varies considerably over time but stays below 6% each year in every age group. As expected, relatively few households changed their mortgage type in the first years after the introduction of IO mortgages, whereas we see more activity from 2010 and forward. In the early years, more households replaced their repayment with an IO mortgage, whereas towards the end of the sample more households have changed their dominant mortgage from an IO to a repayment mortgage. This pattern can be explained by two observations. First, 2014 and 2015 are the first years where the IO-period for the very first IO mortgages run out. Second, interest rates are very low in Denmark during the latest years of our sample, cf. Figure 2, which makes it more affordable to pay down mortgages.

Our finding that the popularity of the IO mortgages has increased since the introduction in 2003 across all age groups is clearly illustrated by Figure 5 which shows the fraction of households holding an IO mortgage in each age group in the years 2004, 2009, and 2014. Young and old households have a higher fraction of IO mortgages compared to middle-aged households, and the

[20] A household is defined as entering the mortgage market if the household does not have any mortgage debt in the two years prior to the entry.

relation between age and IO mortgages has become more U-shaped over time, which indicates an increasing use of IO mortgages to smooth consumption over the life cycle.

[Figure 5 about here.]

In order to investigate whether the age-dependence in mortgage choice is correlated with differences in background characteristics of the households, we run the probit estimation

$$P(D_i^{\text{IO}} = 1|X_i, C_i) = \Phi\left(\beta' X_i + \delta' C_i + u_i\right). \tag{2}$$

Here D_i^{IO} is a dummy variable equal to one if household i's dominant loan is an IO mortgage; X_i is a vector of dummies for nine different age groups (less than 34, 35-39, ..., 70+); and Φ is the standard normal cumulative distribution function. The C_i in Eq. (2) is a vector of control variables and includes the mortgage interest type (ARM/FRM), the logarithm of current disposable income measured in Danish Kroner, the debt-to-asset ratio, the number of borrowers, the number of residents (adults and kids), the household type, the gender, the educational level, as well as regional dummies and time dummies. The probit estimation requires that each household is only present once, hence we represent each household by the origination year. To avoid selection problems with respect to which households borrow after 2003, we only use mortgages originated after 2003.

[Table 2 about here.]

Table 2 presents the average partial effects (APE) together with robust standard errors in parentheses. The age group of 45-49 years is used as the base group. The table shows that the two youngest groups have a significantly higher probability of holding an IO mortgage compared to a middle-aged household with similar characteristics. Specifically, the youngest group has a 6.8% higher probability of holding an IO mortgage compared to an household aged 45-49 years, whereas the second youngest group has a 1.1% higher probability. For the four oldest groups of homeowners (age 55 and above), we also see an increasing probability of having an IO mortgage. At age 70 and above, the likelihood of taking an IO mortgage is as much as 34.2% higher than for the base group. These results confirm that IO mortgages are more popular among young and old homeowners than among middle-aged homeowners also after controlling for background characteristics.

Table 2 further shows how mortgage choice is affected by the control variables after separating out the age dependence. We see that homeowners are less likely to hold an IO mortgage when the mortgage has a fixed rate instead of an adjustable rate, when current income level is higher, a

male borrower is present, and when the household consists of more adults. On the other hand, the likelihood of holding an IO mortgage increases with the number of children, the education level, and the debt-to-asset ratio.

As indicated by Figure 5, there is a time-trend in the propensity to take out an IO mortgage, and the difference between the take-up of IO mortgages between age groups has increased over time. If this time-trend correlates with the inflow of new and younger customers this might influence our estimates in our probit regression. As mentioned, we include year-fixed effects, which should alleviate this concern, but as an additional check, we rerun the probit estimation stated in Eq. (2) year by year. Figure 6 displays the average partial effects across the age groups in year 2004, 2009, and 2014. For the households above 45, we see that our results are robust over time, whereas the young have increased their tendency to take out an IO mortgage.

[Figure 6 about here.]

For probit models with fixed effects, the estimates are generally statistically inconsistent. As a robustness check, we did a similar analysis using OLS with fixed effects and found comparable results for the two estimation methods, cf. Table IA.4 and Figure IA.4 in the Internet Appendix. This suggests that the findings in Table 2 and Figure 6 are not a result of inconsistent estimates caused by the use of a non-linear estimation method with fixed effects.

3.2 Consumption smoothing

A standing assumption in financial economics is that households would like to smooth consumption over the life cycle so that consumption is less volatile than income. Labor income typically starts out at a low level, increases significantly until age 45-55, and subsequently flattens out or even drops somewhat until retirement (Cocco, Gomes, and Maenhout, 2005; Guvenen, Karahan, Ozkan, and Song, 2021). Consumption smoothing is thus the key motivation for retirement saving and for why young households often borrow funds and pay back when their income has increased. The access to an IO mortgage grants households more flexibility in life-cycle consumption planning and, in particular, facilitates consumption smoothing. More specifically, young households may find IO mortgages attractive as they typically expect significant labor income growth in the coming years. Older homeowners with no or little labor income or pension payouts would like to finance consumption by reducing net wealth. Whereas a repayment mortgage increases net wealth by reducing the outstanding loan balance, an IO mortgage may be attractive, in particular if the homeowner is liquidity constrained in the sense that the home equity constitutes a large share

of total household net wealth. That is, an IO mortgage may allow financially constrained older homeowners to stay in their home and avoid a stressful and costly process of selling and moving.

Section 3.1 already documented that young and old homeowners are more inclined to take an IO mortgage than middle-aged homeowners, which is consistent with the above consumption smoothing mechanisms. Figure 7 gives further support to this motivation. It depicts estimated life-cycle consumption and income profiles for households with an IO mortgage and households with a repayment mortgage. Panel A shows that homeowners with an IO mortgage tend to consume more than current income when they are below 35 and above 65 years, whereas middle-aged IO borrowers tend to be net savers. Panel B illustrates that homeowners with repayment mortgages tend to consume less than their current income and thus be net savers throughout their life cycle. These graphs indicate that IO borrowers engage more in consumption smoothing than borrowers with a conventional repayment mortgage.[21] The following two subsections dig deeper by investigating the motives behind the IO mortgage choice separately for young and for old households.

[Figure 7 about here.]

3.3 Young households and expected income growth

According to the consumption smoothing motive, borrowers should be more inclined to take an IO mortgage the higher is their expected future income growth, as also argued in Cocco (2013). To test this hypothesis with our data, we rerun the probit estimation stated in Eq. (2) with income growth added to the list of explanatory variables. As households' expected income growth is unobservable, we follow Cocco (2013) and measure the expected annual income growth rate by the average annual realized change in the logarithm of disposable income over h years, i.e.,

$$\text{income growth} = \frac{\ln(\text{income}_{t+h}) - \ln(\text{income}_t)}{h}.$$

Larger values of h reduce the noise in the income growth measure, but also lead to fewer observations in our sample. Figure 8 shows the average partial effect of income growth measured over $h = 7$ years on the likelihood of having an IO mortgage across the different age groups; similar patterns are seen for $h = 4, 5, 6$.[22] We see that the impact of future income growth on the likeli-

[21] Ideally, we would have liked to compare the *actual* life-cycle profiles of households with an IO mortgage to households with repayment mortgages but, due to the time-span of our data, this is impossible. Instead, inspired by Betermier, Calvet, and Sodini (2017), we sort households by birth year into different cohorts using balanced data, and estimate the life-cycle profile of the two different types of households as seen in Figure 7. The precise estimation method is described in Section IA.2 in the Internet Appendix.

[22] We add the same control variables as for the probit estimation in Eq. (2) and find similar effects. For example, the effects of education on the probability of holding an IO is at the same level as in Table 2.

hood of choosing an IO mortgage is large and positive for the young, is decreasing with age, and ends up small and even negative for households above 55.[23] Specifically for the youngest group of households, the likelihood that the household has an IO mortgage increases by approximately 100% when annual income growth over seven years increases by 1%. This clearly indicates that some households use IO mortgages to release money today when income is relatively low and wait repaying their mortgage until their income is higher. This supports the hypothesis that consumption smoothing over the life cycle by postponing repayments to periods with higher income is concentrated among younger households. The findings are consisting with the conclusion of Cocco (2013) on a smaller sample of UK households of age 20-60. We refine his conclusion by showing that the income growth is driving IO take-up only among the younger households and, in fact, income growth has the opposite effect on IO choice among older households.[24] Other factors must explain the strong tendency for old households to use IO mortgages.

[Figure 8 about here.]

Using an alternative measure of permanent income in different education and occupation groups, Cocco (2013) finds that groups with higher income variance are less likely to choose an IO mortgage. However, for the variance-effect to be significant, income growth has to be excluded from the regression and, as noted by Cocco (2013), income risk and income growth are highly collinear. Cocco's finding could potentially explain the inclination of older households towards IO mortgages as they face relatively low income risk. It is not clear, though, why households with lower income risk should have a higher demand for IOs. In fact, households with uncertain income benefit from having an IO mortgage since the lower mortgage payments help them staying in their home should income temporarily fall. In the internet appendix, Table IA.3 shows that in our sample the IO take-up is similar among households with at least one self-employed adult as among households with no self-employed adults, even though self-employed typically have a more uncertain income. Moreover, Figure IA.8 shows that income volatility is positively correlated with the probability of having an IO mortgage for all age groups, but the correlation decreases with age and becomes insignificant for the oldest age group.

[23] As for the other probit estimation, we ran an OLS estimation with fixed effects as a robustness check, and found comparable results, cf. Figure IA.5 in the Internet Appendix.

[24] The average mortgage holder is 34 years in Cocco's sample but 48 years in our sample.

3.4 Old households and liquidity constraints

For older homeowners, we hypothesize that liquidity needs are the main driver of the demand for IO mortgages. Liquidity-constrained households have an incentive to free up needed liquidity by taking an IO mortgage and spend the saved repayments in order to maintain a given consumption level. Using a term coined by Kaplan and Violante (2014), some old households are "wealthy hand-to-mouth": they hold little or no liquid wealth but at the same time highly valuable illiquid assets in the form of home equity after having paid down their mortgage. Kaplan and Violante (2014) argue that wealthy-hand-to-mouth households should be more responsive to fiscal stimulus. In the same vein, our hypothesis is that the introduction of IO mortgages should impact constrained households more than unconstrained households.

To measure how liquidity constrained a given household is we calculate the illiquid-asset-ratio

$$\text{IAR} = \frac{\text{Public property value} - \text{Outstanding mortgage debt}}{\text{Total assets}},$$

where the numerator is a measure of the home equity, and the denominator includes cash, bank deposits, stock and bond holdings, as well as the public property value of all properties owned by the household (the public property value is explained in footnote 11).[25] A high IAR indicates that a large share of the household's assets are held as relatively illiquid home equity. Figure 9 shows that, except for very young households, the fraction of households with an IAR above 50% increases with age, and old households are the most liquidity constrained.[26]

[Figure 9 about here.]

To get a better understanding of the relation between a household's illiquid-asset-ratio and the probability of taking up an IO mortgage, we run the probit estimation

$$P(D_i^{\text{shift}} = 1|C_i) = \Phi\left(\beta_1 \,\text{IAR}_i + \beta_2 \,\text{DTA}_i + \beta_3 \,\text{IAR}_i \times \text{DTA}_i + \delta' C_i + u_i\right) \tag{3}$$

for each age group. D_i^{shift} is a dummy variable equal to one if household i refinances a repayment mortgage to an IO mortgage, and DTA_i is the debt-to-asset ratio. We include only households with a repayment mortgage in the regression, and exclude first-time homeowners and households

[25] Note the IAR measure is not directly comparable to the "wealthy hand-to-mouth" measure used in e.g. Kaplan and Violante (2014). Most importantly the IAR measure does not include pension savings as part of the household's illiquid assets.

[26] The denominator in the IAR ratio is typical lower for young households. On top of this, banks might also require a higher down-payment for very young households buying their first home. This can explain why the fraction of households with an IAR above 50% decreases in age for households below 30.

already holding an IO. To ensure all households are represented only once, we use data for the year where the given household refinances, if it does, and a random year if it does not refinance its mortgage in the period 2003–2011. To account for the economic situation of the household the year it refinances, various control variables are lagged one period, e.g. the debt-to-asset ratio, the illiquid-asset-ratio, the mortgage interest type (ARM/FRM), and income. We also include a dummy for a negative income shock of more than 10%, e.g. due to sudden unemployment, as this could raise an immediate need for liquidity and hence affect the probability of converting a repayment mortgage to an IO. We include both the current and a one-period lagged dummy for the negative income shock. We control for the number of borrowers, the number of residents (adults and kids), the household type, the gender, the educational level, as well as regional dummies and time dummies. From Section 3.3 we know that future income growth is a good predictor of young households' demand for IOs. Hence, we also control for future income growth.[27] The results from the probit regression can be seen in Table 3.

[Table 3 about here.]

Table 3 shows that a high illiquid-asset-ratio has a positive effect on the probability of refinancing a repayment mortgage with an IO mortgage. The effect is significant for all age groups, but larger for the older households where IAR has the largest explanatory power. A negative income shock also has a positive effect on the probability of refinancing to an IO mortgage, again with the effect increasing in age. For the middle-aged group, a negative income shock could come from a job loss, but as also seen in Andersen et al. (2020a) unemployment has a modest effect on refinancing to an IO mortgage as the borrower is typically prevented from refinancing by the mortgage bank due to the unemployment status. For an older household, a negative income shock might follow from the death of a spouse. If the household at the same time has a high IAR, a conversion from a repayment mortgage to an IO mortgage can allow the widow(er) to stay in their home, and avoid a potentially stressful and costly process of selling and moving. In line with our earlier results, income growth has the highest explanatory power for the young households, whereas the IAR has the highest explanatory power for the oldest households.

[Table 4 about here.]

To test our hypothesis that the introduction of IO mortgages should impact constrained households more than unconstrained households we use a difference-in-differences (diff-in-diff) estimation

[27] Here we calculate income growth over only four years to reduce the loss of observations. Our results are similar when using longer periods for estimating income growth, but less significant due to fewer observations.

in which the IO introduction in late 2003 is considered an exogenous shock, cf. the discussion in Section 2.2. Before going into details with the diff-in-diff estimation, consider the sample used in this analysis. The left part of Table 4 shows summary statistics for households with an average age above 60 for the two sub-periods before and after the introduction of IO mortgages. When comparing these with the summary statistics for our full sample in Table 1, we see, as expected, that households above 60 have lower debt, lower debt-to-asset ratios, lower income, higher loan-to-income, lower consumption, higher use of IOs, and more live as singles. Comparing the two subperiods in Table 4, we note that total debt, income, and consumption increases over the two subperiods, and the same pattern is seen for the full sample in Table 1. Finally, we note that the average IAR equals 53%, i.e. more than half of the wealth of old households is tied up in their home, compared to approximately 38% for the full sample. This is consistent with the pattern seen in Figure 9.

As our sample starts in 2001, we calculate pre-shock consumption over 2001–2003 and, to balance the before- and after-period, we measure post-shock consumption over 2004–2006. In each of these years and for each household we calculate the IAR defined above. The treatment group includes households having a high IAR, defined as 50% or more, throughout the 2001–2003 period. The control group consists of households having an IAR below 50% in 2001–2003.[28] To align our treatment and control groups, we use matching in the form of a one-to-one matching minimizing the difference in the propensity score. The matching is based on year 2002 values, and the same low IAR-household is used as the match for each high-IAR homeowner through time. Replacement is allowed, meaning that each low IAR-household can appear as match for several high-IAR homeowners.[29] Replacement improves the overall match and thereby minimizes the risk of a bias in the diff-in-diff estimation.[30] For completeness, the right panel of Table 4 shows the summary statistics in 2002 for our treatment and control groups, respectively.

To estimate the causal effect of IO mortgages on consumption we run the following diff-in-diff estimation

$$\log(\text{cons}_{it}) = \beta_0 + \beta_1 D_t^{\text{after IO}} + \beta_2 D_i^{\text{high IAR}} + \beta_3 D_i^{\text{high IAR}} D_t^{\text{after IO}} + \delta' C_i^{2002} + u_{it}, \qquad (4)$$

where the dummy $D_i^{\text{high IAR}}$ is an indicator for the treatment group, and the time dummy $D_t^{\text{after IO}}$ differentiates the time before (2001–2003) and after (2004–2006) the shock. The vector of control

[28] Similar results are obtained using a threshold different from 50%.

[29] Almost 60% of the households with low IAR are used as replacement only once, 22% twice, 8.5% three times, and only 3.3% are used more than 5 times.

[30] The parallel trend analysis shown in Figure IA.9 in the Internet Appendix verifies that the trends of consumption before the IO introduction are almost parallel.

variables, C_i^{2002}, includes type of mortgage, logarithm of disposable income, debt-to-asset ratio, number of adults, borrowers, and kids, household type, gender, educational level, as well as regional trends in house prices. All control variables are represented by their 2002-level, i.e., before the introduction of IO mortgages, to make sure that changes in consumption are not driven by changes in the control variables.

[Table 5 about here.]

The results of the estimation are shown in Table 5. As expected, we see a significant effect only for households close to or above the retirement age. For households in the age group 60-64 the introduction of IO mortgages implied an increase in the annual consumption of 6% for households with a high IAR compared to households with a low IAR, whereas households in the age group 65-69 have an increase of 7%, and households above 70 have an increase of 9%. These results point to an important role of IO mortgages for liquidity-constrained older households. By using IO mortgages, these households can free up liquidity, allowing them to consume more. Without access to IO mortgages, these old households would have consumed less and build up an even larger home equity.

One may question whether the consumption increase documented above is due to the general credit expansion we saw in the period leading up to the financial crisis instead of the introduction of IO mortgages itself. To check this, we conduct a placebo test. We run a diff-in-diff estimation similar to Eq. (4), but instead of looking at the period before and after the introduction of IO mortgages, we look at the period before and after the peak of the financial crisis in 2009, i.e. we compare the 2009-2011 period with the 2006-2008 period. Credit supply was tightened in the post-crisis 2009-2011 period, but there was no change to the IO legislation during this period. In this way, we separate the credit-supply effect from the effect of IO access. If the results in Table 5 were due to a credit-supply expansion, we would expect to see the opposite results from this placebo test. However, Table 6 shows that this is not the case. We observe a small significant positive effect for the households of age 35–49 of approximately 2%, i.e. the credit-supply shock in 2009 implied a 2% increase in the annual consumption of households with a high IAR compared to households with a low IAR. The intuition behind this result is that, when observing a significant drop in the value of its home, relatively young homeowners with a low IAR, i.e. low home equity relative to liquid assets, might cut its current consumption more than homeowners with a high IAR. For all other age groups, the results are insignificant. In particular, the credit-supply shock and the level of IAR have no effect on the consumption of older households. Overall, this indicates that our findings in Table 5 are not due to a credit-supply expansion.

[Table 6 about here.]

4 How do households use the extra liquidity from IO mortgages?

Interest-only mortgages have been blamed for leading households into excessive borrowing and consumption. By relaxing a commitment constraint to pay down a mortgage, IO mortgages allow households with preferences for constraining their own future choices (Laibson, 1997) to overconsume, in particular when young. In this sense, financial liberalization, in the form of interest-only loans, may provide consumers with "too much" liquidity. At a first glance, our data might appear to confirm this hypothesis.

The summary statistics in the right part of Table 1 show that IO mortgages are typically larger than repayment mortgages, also relative to household income. Households with an IO mortgage have, on average, lower income but a larger total debt, a larger debt-to-asset ratio, and a significantly larger loan-to-income ratio. Furthermore, IO borrowers have a higher consumption-to-income ratio and make lower pension contributions than borrowers with a repayment mortgage. Overall, these observations seem to justify the concerns often mentioned in the public debate on alternative mortgages. However, such a conclusion is premature. A first indication of this comes from calculating default frequencies after the burst of the house-price bubble in 2008. If households with IO mortgages leveraged up too much before the financial crisis, one would expect a higher degree of defaults among IO borrowers following the post-crisis drop in house prices, cf. Figure 4. But we find no substantial difference between default rates of IO and repayment borrowers. The average fraction of loans between 2009 and 2016 in arrears for 105 days is 0.28% for IO and 0.22% for repayment mortgages. An interesting implication is that even if households did not fully comprehend the IO features—as explored by Johnson and Sarama (2015) and Jørring (2020) using US data—IO borrowers in our Danish data set did not seem to experience more financial difficulties than repayment borrowers during times of financial stress. There are several reasons for the similarity in default rates, and why default rates are low in general. First, for most IO mortgages in Denmark, amortization starts 10 years after issuance, which means in 2013 or later and thus not in the midst of the financial crisis.[31] Secondly, IO mortgages may only be issued to households that could afford a repayment mortgage. Thirdly, should an IO borrower be financially challenged when the amortization period begins, the mortgage institutions and banks can often

[31] It follows from Figure 4 that house prices in 2013 and forward are at the same level or above the prices in 2003, and hence the affected households can refinance to a new IO mortgage if needed. Some regions in Denmark did not see an increase in house prices after the financial crisis and hence faced the problem with the end of the IO period. This is investigated in detail in Andersen, Beck, and Stefani (2020b).

offer a refinancing package allowing the borrower to stay in the home.[32]

In the next sections, we use the fact that we have detailed data on different types of debt and the asset composition of the households to see whether households with IO mortgages reshuffle their debt composition in meaningful ways and whether IO mortgages influence the asset composition and pension contributions of households.

4.1 Reduction in life-time borrowing costs

By taking an IO mortgage, households can pay down more expensive bank and credit card debt instead of their mortgage, and hence reduce life-time borrowing costs. Figure 10 gives a detailed picture of the financial situation of households with an IO mortgage and households with a repayment mortgage, respectively. The figure is designed like Figure 7 but illustrates patterns of total debt, other debt (i.e. bank debt and other types of non-mortgage debt), cash (balance of bank account), market value of stocks and bonds, public valuation of the home, and the contribution to pension saving schemes over the life cycle. In this section, we focus on mortgage debt and other debt, i.e. Panels (a) and (b). The four other panels are discussed in subsequent sections.

[Figure 10 about here.]

Panel (a) of Figure 10 shows that, at all ages, homeowners with IO mortgages have higher mortgage debt relative to income than homeowners with repayment mortgages. The distance between the two curves increases with age due to the drop in income, not an increase in mortgage debt.[33] Panel (b) illustrates that other debt relative to income is decreasing over the life cycle. Until the age of 72, other debt is higher for homeowners with an IO mortgage than for homeowners with repayment mortgages, whereas the reverse is true for households older than 72 years. This indicates that homeowners with IO mortgages tend to take up more non-mortgage debt when young, but repay that non-mortgage debt more rapidly than homeowners holding a repayment mortgage.

Motivated by these patterns, we run the simple OLS regression

$$y_i = \beta_0 + \beta_1 D_i^{IO} + \delta' C_i + u_i, \tag{5}$$

[32] See Berg, Nielsen, and Vickery (2018) for a detailed description of the differences between the Danish and US mortgage market and further explanations for the generally low default rates in Denmark.

[33] In absolute terms the value of mortgage debt is higher for households with IO mortgages over the entire life cycle. Also, for both types of households we see a drop in the absolute value of their total mortgage debt. These results are available upon request.

where y_i is the ratio of other debt to total debt for household i, and C_i is the vector of the standard control variables. Table 7 presents the results. We find that, for age 40 and above, IO borrowers have a lower fraction of other debt relative to total debt than borrowers with repayment mortgages. For example, a household in the age group 55–59 with an adjustable-rate IO mortgage has a 3.0 percentage points lower debt-ratio than a similar household with an adjustable-rate repayment mortgage. If the household instead had a fixed-rate IO mortgage, the debt-ratio would be 2.1 percentage points lower compared to a household with a fixed-rate repayment mortgage (the sum of the three coefficients in the column 55–59 is -0.021). Interestingly, we see this pattern only for the middle-aged and old households, whereas the young households with an IO mortgage have a higher fraction of other debt relative to total debt. Hence, it seems that, except for young households, IO mortgages are used for reducing financial costs related to other, more expensive loans.

[Table 7 about here.]

4.2 Improved diversification

Homeowners may benefit from reducing their mortgage repayments and instead investing in financial assets to obtain a more diversified portfolio. Panel (c) of Figure 10 shows that homeowners with repayment mortgages hold more money in bank accounts relative to income than homeowners with IO mortgages. This indicates that IO mortgages are not chosen with the purpose of increasing cash balances.

On the other hand, Panel (d) reveals that savings in stocks and bonds relative to income are slightly higher for homeowners with IO mortgages. The market value of stock and bond holdings relative to income increases with age both for IO borrowers and borrowers with repayment mortgages but, in particular for middle-aged and older households, financial asset holdings are larger for IO borrowers. This suggests that some age groups might choose IO mortgages to increase investments in stock and bonds. To explore the effect in more detail, we run the probit estimation

$$P(D_i = 1|X_i, C_i) = \Phi\left(\beta' X_i + \delta' C_i + u_i\right), \tag{6}$$

where D_i is a dummy variable equal to one if household i holds stocks, X_i is the vector of interest and includes dummies for the nine different age groups, and C_i is a vector of standard control variables. The probit estimation requires that each household is only present once, hence we represent each household by a random year after 2003. The results listed in Panel A of Table 8 show

that the probability of investing in stocks increases with approximately 5% for middle-aged and old households with an IO mortgages, whereas among young households IO borrowers are slightly less inclined to participate in the stock market than borrowers holding a repayment mortgage.[34] These findings question the view that risk tolerance is a key driver of mortgage choice as was suggested by Cox et al. (2015). If IO mortgages are predominantly taken by more risk-tolerant households, we should see more stock market participation among IO borrowers across all age groups, but the younger households contradict this pattern.

Based on a simple probit regression, we cannot reject that there are unobservable determinants driving both the choice of IO mortgages and higher participation rates in stocks. We have estimated several diff-in-diff specifications using the introduction of IO mortgages to say something more precise about causality. First, Panel A of Table IA.5 in the Internet Appendix shows the results of a diff-in-diff regression similar to Eq. (4), but with stock market participation as the dependent variable, so that we test whether the IO introduction affected stock market participation differently for the liquidity-constrained, high-IAR homeowners than the low-IAR homeowners. We see no significant effect of the IO introduction in any of the age groups. This is not surprising given the empirical literature showing that indirect entry costs (representing, e.g., lack of knowledge) are central for the stock market participation decision, and the IO introduction has no obvious effect on these costs. However, households already investing in the stock market have paid the entry costs so they might increase their stock investments when getting access to IO mortgages. Hence, in a second diff-in-diff regression where we restrict our sample to households that at some point in time have participated in the stock market in the 2001–2006 period, we hypothesize that households with a high IAR increase their allocation to stocks after the introduction of IOs compared to households with a low IAR. That is, we rerun the diff-in-diff estimation stated in Eq. (4) with

$$\text{RAS} = \frac{\text{Market value of stock holdings}}{\text{Market value of bank deposits, stock-, and bond-holdings}}$$

as the dependent variable. The results in Panel B of Table IA.5 show that, in the age group 55–59, households with a high IAR increase their risky asset share by 2.8% more compared to households with a low IAR due to the introduction of IO, and the effect is significant at the 5% level. For all other age groups, the effect is smaller and insignificant. So while the proofs of causality are limited, our results indicate that some middle-aged households choose IO mortgages to increase

[34] When running the probit estimation with D_i indicating participation in the stock or the bond market (or both), the age group coefficients are slightly higher, e.g., 0.063 for the 60-64 year old instead of 0.058 with stock market participation only. Details are available upon request.

stock investments.[35] The old and the young seem to use IO mortgages for other purposes. For example, Table 6 shows that an old household with an IO mortgage has a higher probability of holding stocks, but the results from the diff-in-diff regressions indicate that old households do not take an IO mortgage to buy stocks, but to smooth consumption as illustrated in Table 5.

4.3 Pension contributions

As explained by Amromin et al. (2007), homeowners may, under some conditions, benefit from reducing their mortgage repayments and instead increase their contributions to retirement saving accounts. Panel (f) of Figure 10 shows that pension contributions in our data are hump shaped, peaking around the age of 45, and turning negative in the late 60s when the pension payout period typically starts. Pension contributions seem almost unrelated to the mortgage type. To investigate this in more detail, we first run a probit estimation similar to Eq. (6), but with the dummy variable D_i being equal to one if household i contributes to a private pension saving account. All working households in Denmark pay into a labor-market pension program. On top of that, households may voluntarily pay contributions to a private pension scheme. Hence, our probit regression tells us if households with an IO mortgage are more likely to make voluntary pension contributions, in this case indicating that they use some of the saved repayments to pension contributions. Panel B of Table 8 shows that very young households are less likely to make private pension contributions if they have an IO mortgage. On the other hand, households above 55 seem to use the saved repayments to pay into a private pension.

To get an idea of the magnitude, we run an OLS regression similar to Eq. (5), but with the dependent variable y_i being the average total pension contribution per adult per year. Panel C of Table 8 shows that households above 45 with an IO mortgage make larger voluntary pension contributions. For example, in the age group 50-54 a household with an adjustable-rate IO mortgage pays on average 4,761 DKK more into their pension account per adult compared to a household with an adjustable-rate repayment mortgage. A household with a fixed-rate IO mortgage pays 7,198 DKK more into their pension account than a household with a fixed-rate repayment mortgage. Interestingly, the coefficients are only significant for households in the age groups 45-49, 50-54, and 55-59, and the biggest difference is seen for households of age 50-54. Hence, it seems that households in their late 40s and 50s use some of the saved repayments from their IO mortgages to increase their pension savings, and in this way smooth consumption over the life cycle.

[35] As in other European countries, the stock market participation rate in Denmark is low which implies a low number of observations and thus makes it difficult to show significance.

[Table 8 about here.]

Amromin et al. (2007) suggest that non-conventional mortgages can be used by US households to set up a tax-arbitrage strategy. US households can save taxes by reducing repayment of mortgage debt and investing a similar amount in tax-favored retirement saving schemes (in mortgage bonds or similar assets to keep the overall risk unchanged). In Denmark, a similar arbitrage-like strategy can be implemented by homeowners who (i) have less than ten years to retirement and can thus take an IO mortgage at least until retirement and (ii) pay the highest marginal tax rate while working but a lower tax rate during retirement. Consider, for example, a mortgage with a 2% interest rate and a 0.5% contribution rate to the issuer. Since tax deductability of interest rate (and contribution) expenses is about 25%, the after-tax borrowing cost is $(2\% + 0.5\%) \times (1 - 0.25) = 1.875\%$. This represents the costs of postponing the repayment of the loan. By investing the saved repayment in a similar 2% mortgage bond through a pension fund, the return is taxed at a rate of 15.3%, leaving an after-tax return of $2\% \times (1 - 0.153) = 1.694\%$, which is lower than the saved mortgage costs and thus apparently not an arbitrage. However, pension contributions are deductable from labor income so the household can increase their investment by more than the saved repayment. On the other hand, pension payouts are also taxed as labor income but, due to the progressive tax system, the income tax rate for some households is considerably higher before retirement when the extra pension contributions are made than after retirement where income is typically lower and where the extra pension payouts are received. For such households an arbitrage-like strategy involving IO mortgages is possible also in a Danish context.[36] Unlike the case for some retirement saving schemes in the US, pension savings can only at a high cost be paid out prematurely in Denmark (premature pension payouts are taxed heavily to discourage such withdrawals), so the above strategy is not feasible for younger households. As mentioned, Panel B of Table 8 reveals that in particular households above 50 seem to have used saved repayments to increase pension contributions. Given that the average retirement age in Denmark is around 65, this could reflect the tax arbitrage described above.

5 Summary and conclusion

We make two main contributions to the literature on households' use of IO mortgages. First, we show that there is not a uniformly positive relation between households' future income growth and their use of IO mortgages. The relation is positive for young households, as has been reported in the literature, but negative for old households. To explain the large use of IO mortgages among

[36] This strategy is sometimes discussed in the Danish media and on webpages of Danish pension funds.

old households, we propose and verify empirically that IO mortgages relax an otherwise binding liquidity constraint, by allowing old households to reduce repayment of existing mortgages, thereby increasing liquidity and improving consumption smoothing.

Second, based on our detailed data on the debt and asset composition of households, we show that households with IO mortgages are more indebted, but pay down non-mortgage debt to a larger extent, save more in stocks, and contribute more to pension savings, compared to households with repayment mortgages.

Several of our findings thus indicate that, by relaxing a borrowing constraint, IO mortgages facilitate household consumption smoothing over the life cycle and, in particular, they can improve the welfare of young households expecting increasing income and old, liquidity-constrained households. Furthermore, IO mortgages allow households to reduce life-time borrowing costs and to obtain a better diversified asset portfolio. When assessing the overall welfare implications of IO mortgages, these benefits can be contrasted with the higher leverage of households with IO mortgages.

We look at the microeconomic evidence. We cannot rule out that interest-only mortgages have additional macroeconomic effects that cannot be covered in full when studying microdata. For instance, as mentioned earlier, Dam et al. (2011) find that the introduction of IO mortgages contributed to the surge in home prices during the housing boom in Denmark. This not only harms prospective homeowners but also the broader economy by potentially contributing to boom-bust cycles. Furthermore, increasing the ability for households to lever up may lead to a misallocation of credit to the household sector relative to more productive sectors and can thereby reduce innovation and growth, cf. Jappelli and Pagano (1994). It is outside the scope of this paper to evaluate these macroeconomic effects.

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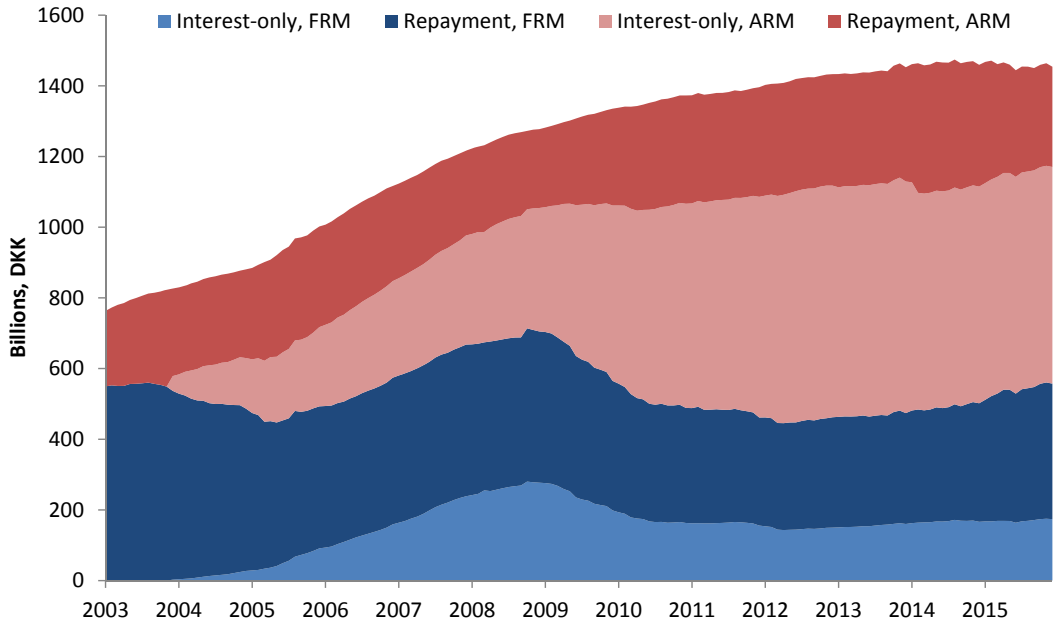

Figure 1: Outstanding mortgages by type. The graph shows the face value of outstanding residential mortgages in Denmark each month in the period 2003–2015. As of 6 October 2021, the exchange rates are DKK 1 ≈ USD 0.155 ≈ EUR 0.134. The total issuance is divided into four subgroups: interest-only FRMs (light blue area), repayment FRMs (dark blue), interest-only ARMs (light red), and repayment ARMs (darker red). Data source: Danmarks Nationalbank.

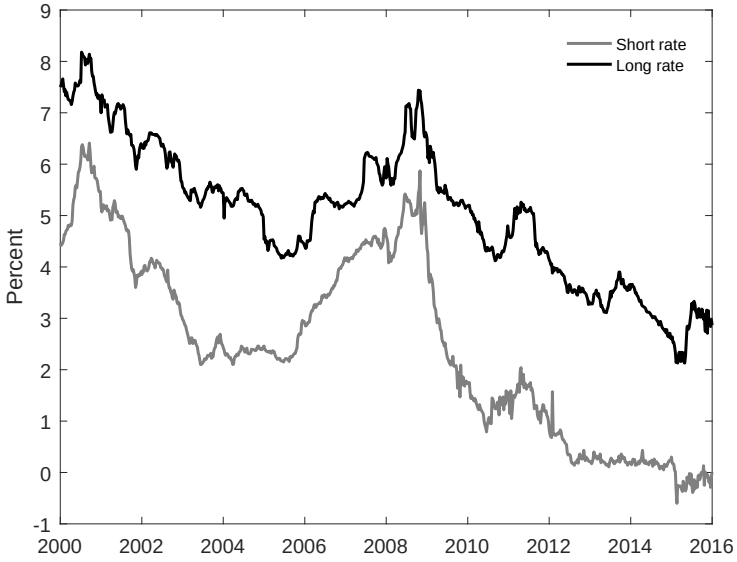

Figure 2: Average Danish mortgage rates in percent. The rates are calculated on a weekly basis and show the average yield-to-maturity on mortgage-backed bonds denominated in Danish Kroner. Data source: Finance Denmark.

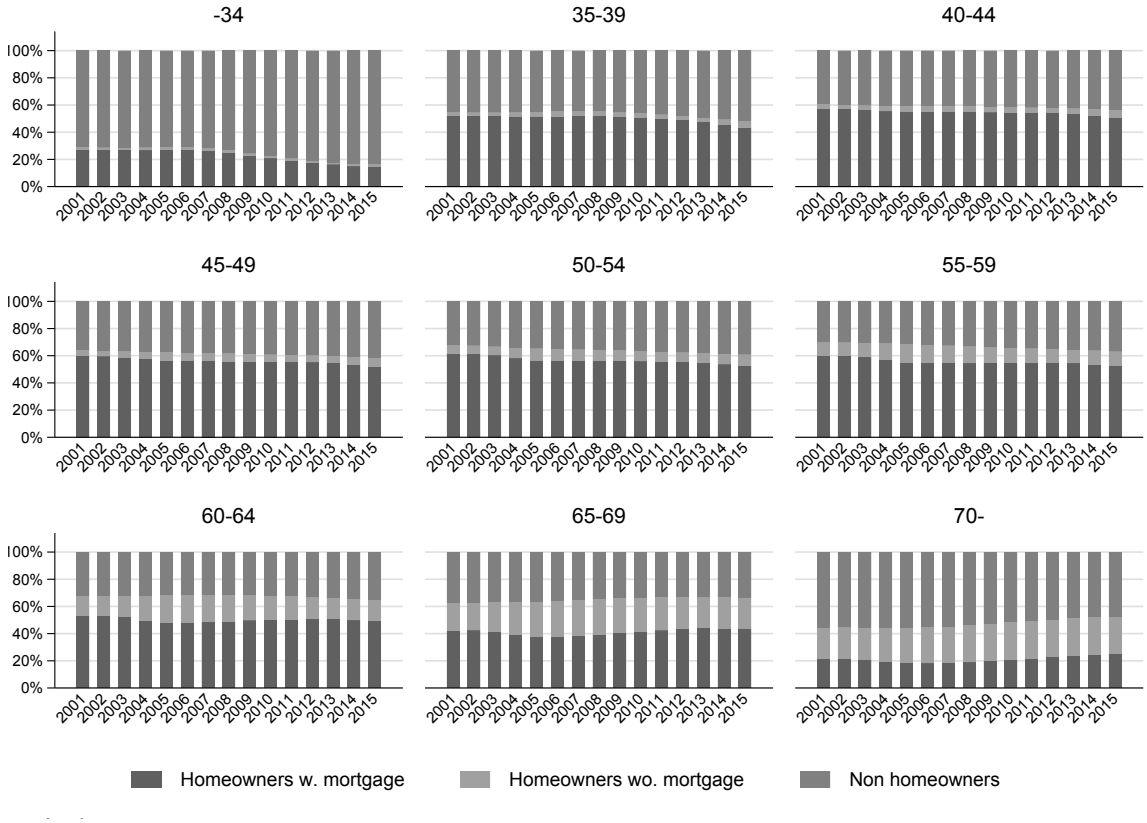

Figure 3: Development of the share of homeowners over time. The diagram shows the development of the share of all Danish homeowners from 2001 to 2015 for the nine different age groups: below 35, 35-39, 40-45, ..., above 70. The dark gray area shows the share of households that are homeowners and have mortgage debt, the light gray area shows homeowners without any mortgage debt, and the medium gray area displays the share of households not owning a house. Data source: Statistics Denmark.

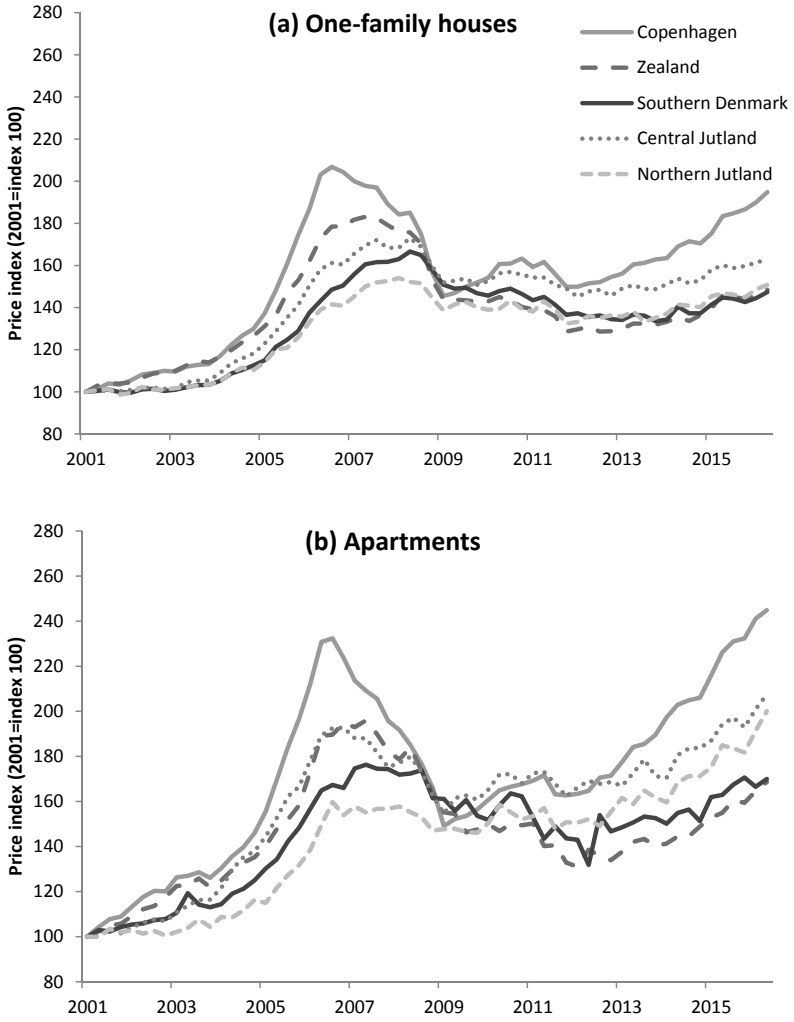

Figure 4: Home prices in Denmark. The graph shows how prices of one-family houses (upper panel) and apartments (lower panel) have developed in the five regions of Denmark in the period 2001–2016. Prices are indexed and fixed at 100 in 2001Q1. Data source: Danmarks Nationalbank.

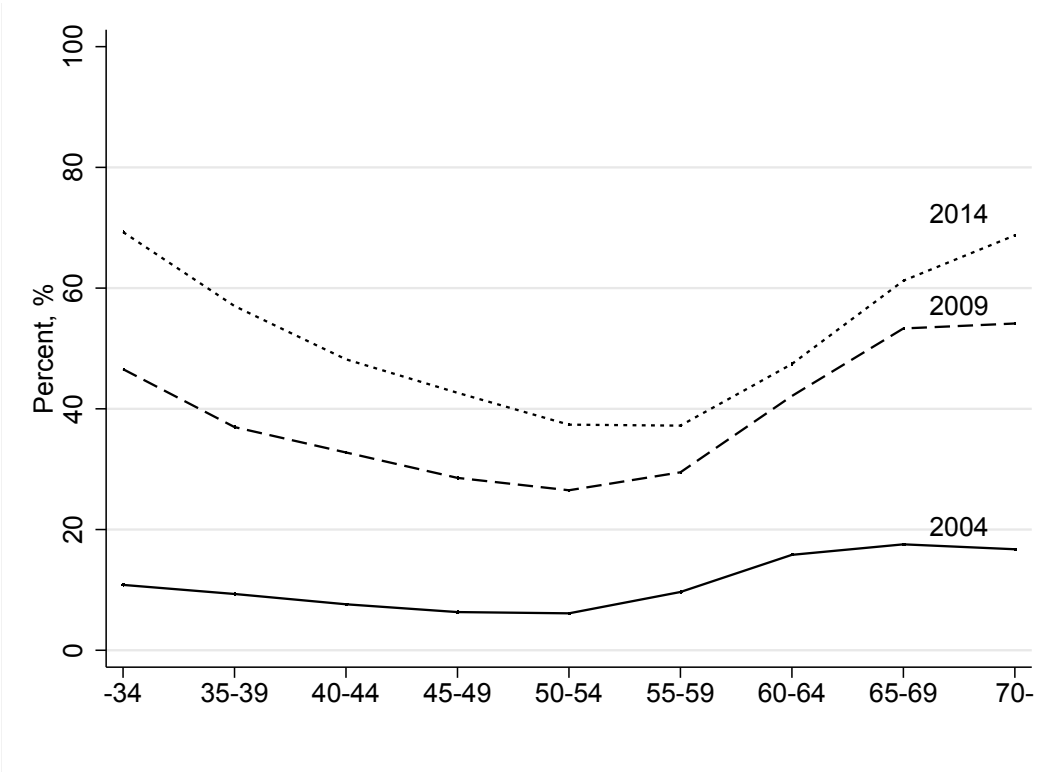

Figure 5: Fraction of IO mortgages. For each of the years 2004, 2009, and 2014, the graph shows the fraction of households in each age group that holds an IO mortgage.

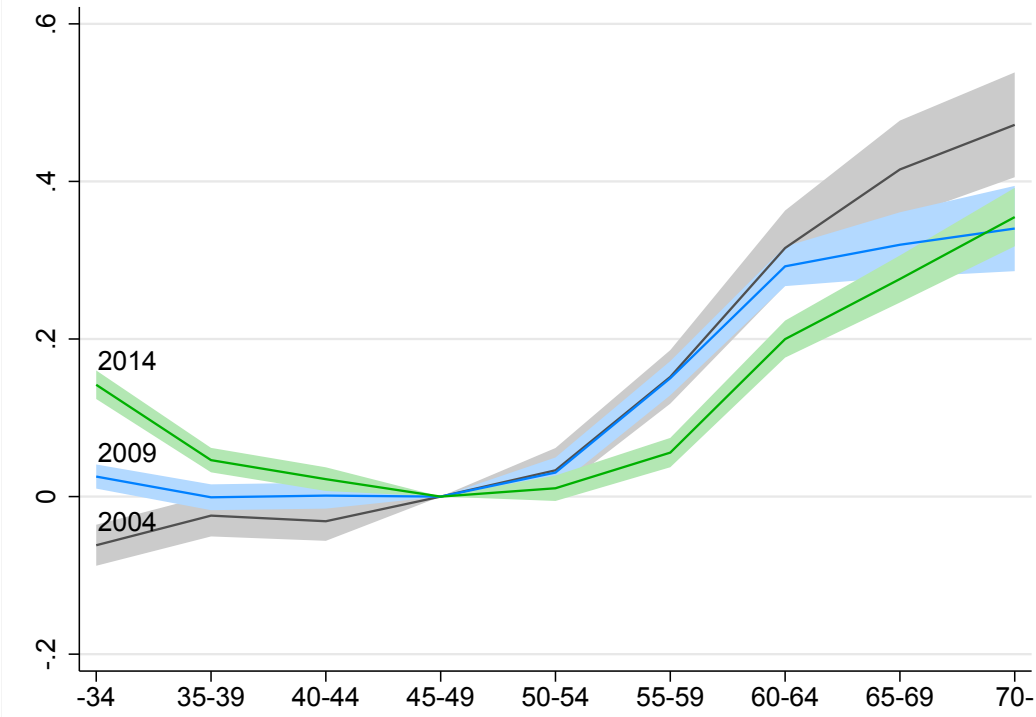

Figure 6: Average partial effects of holding an IO mortgage across age groups. The graph depicts the average partial effects (solid lines) of holding an IO mortgage across age groups in the years 2004, 2009, and 2014. The shaded areas illustrate the 95% confidence intervals. The average partial effects follow from the probit estimation stated in Eq. (2), where the dependent variable is a dummy indicating an IO mortgage. The origination year is used to represent the mortgage choice for each household.

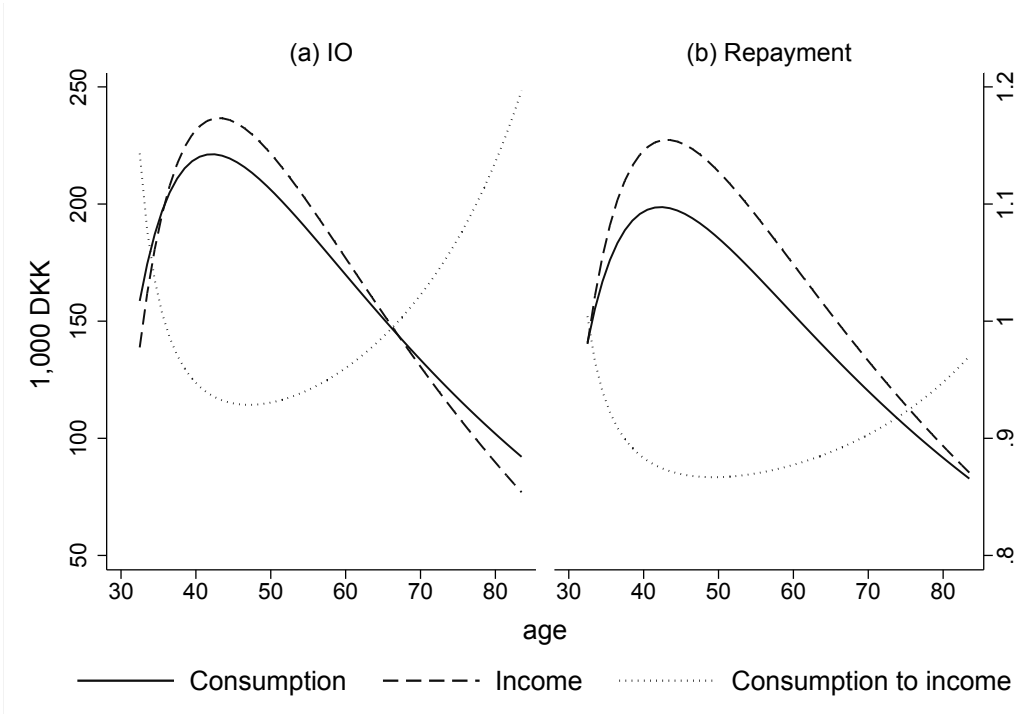

Figure 7: Consumption and income patterns over the life cycle. The graph presents median of annual consumption (solid line), annual income (dashed line), and the consumption-to-income ratio (dotted line; right-hand axis) over the life cycle. Consumption and income are measured as an average per adult in the household. Panel A is based on homeowners holding an IO mortgage at some point within the period from 2004 to 2015, whereas Panel B is based on homeowners holding only repayment mortgages within this time period. The graphs are generated by polynomial fits of nine age groups defined as: below 35, 35-39, 40-44, ..., 65-69, and 70+ in 2004. Each observation for an age group is illustrated at the average age in that group. The graph applies balanced data on homeowners from 2004 to 2015.

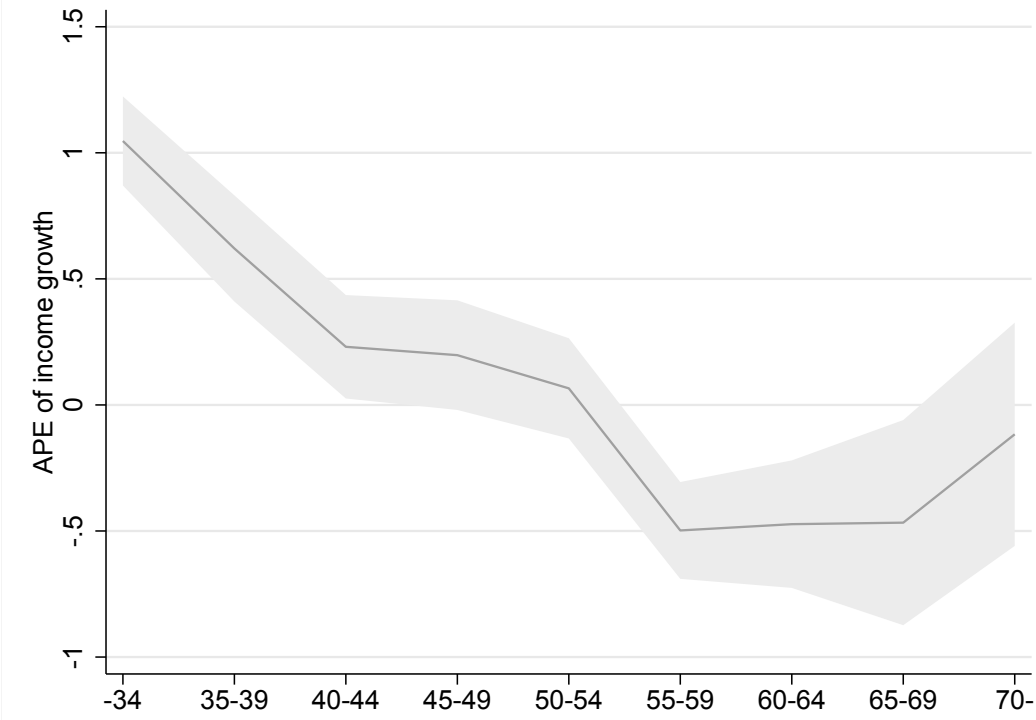

Figure 8: Average partial effects of income growth across age groups. The figure presents average partial effects (solid line) of income growth measured over $h = 7$ years for each age group from the probit estimation stated in Eq. (2) with the income growth rate added to the list of explanatory variables. The shaded area displays the 95% confidence interval.

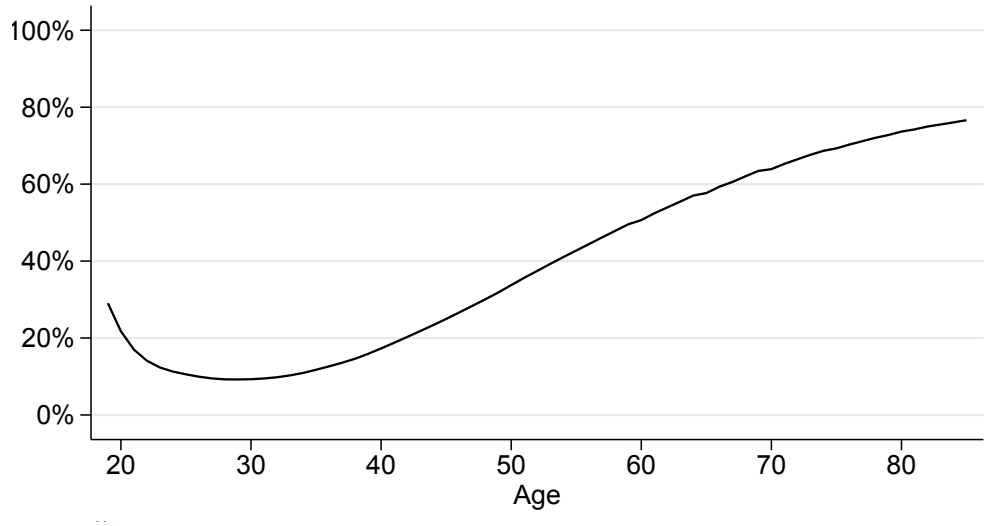

Figure 9: Age profile of fraction of households with IAR $> 50\%$. The figure presents the age profile of the fraction of households with an IAR above 50%. The figure is based on all Danish homeowners in the period from 1995 to 2015.

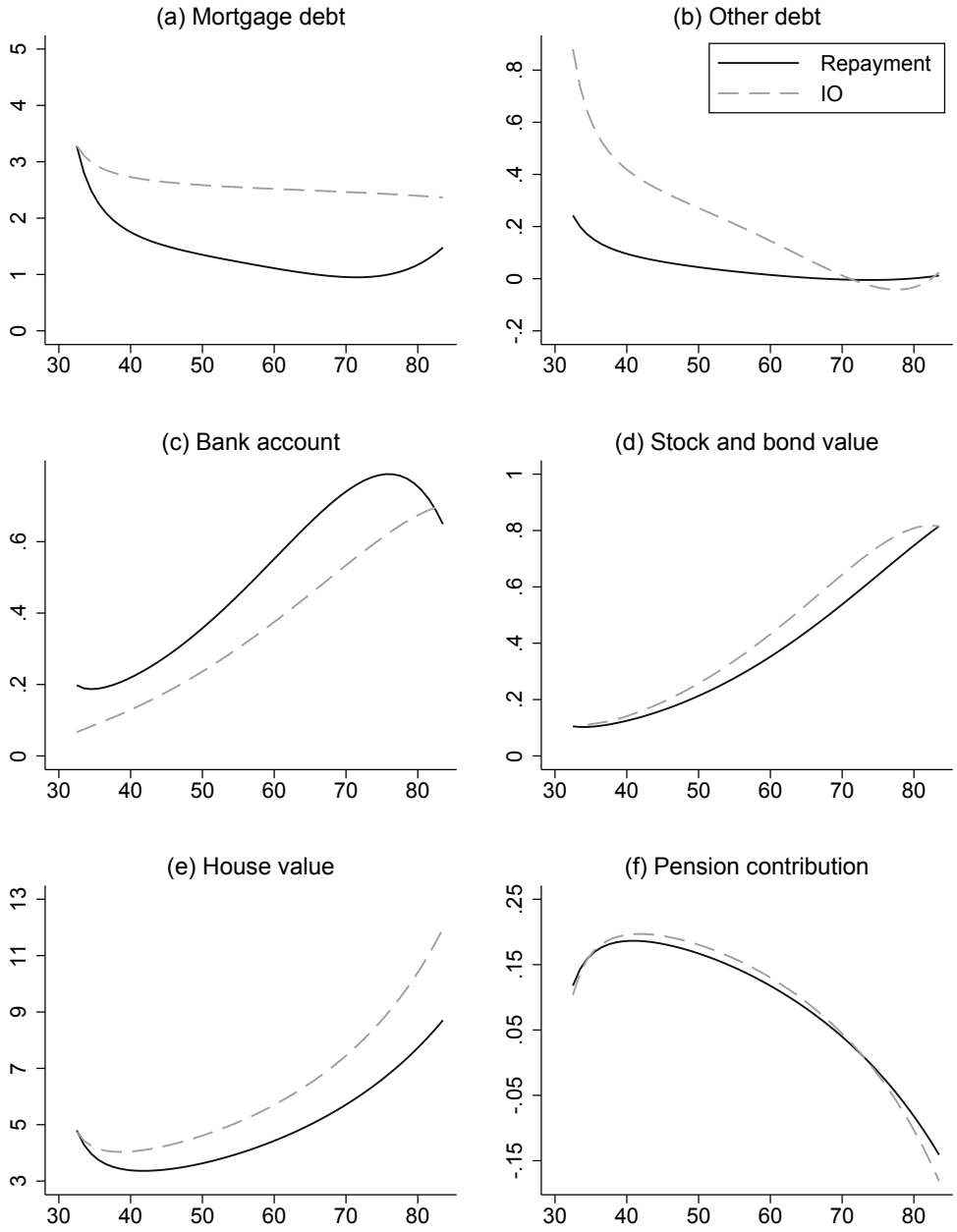

Figure 10: Life-cycle patterns for different financial variables relative to income. The graphs depict medians of mortgage debt, other debt, bank account, public house value, and pension contributions, as well as means of market value of stocks and bonds, from 2004 to 2015 for different age groups and across mortgage type. All variables are measured relative to annual income. The graphs show an overall polynomial fit of all the age groups. Nine age groups are used; below 35, 35-39, 40-44, ..., 65-69, 70 and above in 2004. Each observation for an age group is illustrated at the average age in that group. The dashed curves are based on homeowners holding an IO mortgage at some point within the period from 2004 to 2015, whereas the solid curves are based on homeowners holding only repayment mortgages within this time period. The graph applies balanced data on homeowners from 2004 to 2015.

	By subperiod				By mortgage type	
	2001-02	2003-06	2007-10	2011-15	IO	Repay
CPI (2015=100)	77.48	82.38	88.90	97.64	95.25	93.62
Mortgage characteristics						
Loan amount	316.27	404.13	612.23	721.31	817.79	615.32
LTI	2.24	2.50	3.37	3.36	4.15	2.87
IO mortgage	.	0.14	0.35	0.48		
At least one IO mortgage	.	0.14	0.37	0.51		
Actual IO period	.	0.13	0.34	0.44	0.93	0.00
FRM	0.93	0.70	0.50	0.42	0.33	0.68
Nom. interest rate (%)	6.93	5.03	4.24	2.29	2.46	3.45
Household characteristics						
Total debt	405.73	490.65	710.15	818.79	1003.84	687.23
Debt to Asset ratio	0.63	0.60	0.72	0.87	0.99	0.75
Illiquid Asset Ratio	0.39	0.37	0.31	0.17	0.10	0.25
Income	147.17	168.00	190.56	222.77	206.56	218.90
Consumption	135.94	161.56	184.68	203.09	200.14	199.11
Consumption to Income	0.94	0.99	0.99	0.94	1.01	0.93
Pension contribution	21.13	27.74	36.14	36.70	34.51	40.24
Number of borrowers	1.43	1.51	1.54	1.67	1.66	1.66
Avg. age (borrowers)	48.20	50.43	48.54	50.10	48.68	47.80
age: -34	0.13	0.09	0.16	0.13	0.21	0.14
age: 35-39	0.13	0.11	0.13	0.12	0.13	0.13
age: 40-44	0.15	0.14	0.14	0.13	0.12	0.15
age: 45-49	0.16	0.15	0.13	0.14	0.10	0.15
age: 50-54	0.16	0.16	0.13	0.12	0.08	0.14
age: 55-59	0.11	0.13	0.11	0.11	0.08	0.12
age: 60-64	0.06	0.08	0.09	0.09	0.09	0.08
age: 65-69	0.04	0.05	0.05	0.07	0.08	0.04
age: 70-	0.06	0.08	0.06	0.08	0.10	0.04
Single	0.21	0.21	0.18	0.17	0.18	0.15
Household with several families	0.06	0.06	0.05	0.05	0.05	0.05
Couple	0.73	0.73	0.77	0.78	0.76	0.81
Male	0.88	0.88	0.90	0.90	0.88	0.92
Number of adult residents	1.76	1.77	1.81	1.81	1.80	1.84
Number of kids	0.85	0.80	0.91	0.92	0.92	0.98
Education level 1	0.17	0.15	0.11	0.10	0.09	0.09
Education level 2	0.46	0.44	0.45	0.43	0.42	0.43
Education level 3	0.38	0.41	0.43	0.47	0.48	0.48
Region Copenhagen	0.22	0.22	0.17	0.16	0.20	0.15
Region Zealand	0.14	0.15	0.14	0.14	0.14	0.12
Region South Denmark	0.29	0.29	0.28	0.27	0.25	0.28
Region Middle Jutland	0.22	0.22	0.26	0.27	0.26	0.27
Region North Jutland	0.13	0.12	0.15	0.16	0.15	0.17
Observations	69,492	248,915	904,666	1,441,350	257,541	329,409
Total observations	2,664,423				586,950	

Table 1: Summary statistics. The table presents average values related to the dominant mortgages. Loan amounts, debt, income, consumption, and pension contributions are in DKK 1,000, and measured as an average per adult in the household. For each subperiod the average value over the years is displayed. In the right panel, a random year of each mortgage is used as representative of the mortgage to ensure that each mortgage is weighted equally. Using a t-test, we find that all means for the two mortgage types are statistically different on a significance level of 1%, except for the educational levels. See Section 2 for a more detailed description of variables.

	APE	Robust SE
Age: -34	0.068***	(0.003)
Age: 35-39	0.011***	(0.003)
Age: 40-44	0.006	(0.003)
Age: 50-54	0.017***	(0.003)
Age: 55-59	0.108***	(0.004)
Age: 60-64	0.233***	(0.005)
Age: 65-69	0.294***	(0.006)
Age: 70-	0.342***	(0.007)
FRM	-0.306***	(0.002)
Log bank account	-0.002***	(0.001)
Log income	-0.151***	(0.003)
Debt to Asset ratio	0.227***	(0.002)
Male	-0.050***	(0.004)
Education level 2	0.022***	(0.003)
Education level 3	0.036***	(0.003)
Number of borrowers	0.012***	(0.002)
Number of adult residents	-0.049***	(0.006)
Number of kids	0.015***	(0.001)
Single	0.023***	(0.006)
Region Zealand	-0.071***	(0.003)
Region South Denmark	-0.140***	(0.002)
Region Middle Jutland	-0.103***	(0.002)
Region North Jutland	-0.137***	(0.003)
Observations	290,494	
Pseudo-R^2	0.236	

Standard errors in parentheses

* $(p < 0.05)$,** $(p < 0.01)$,*** $(p < 0.001)$

Table 2: Characteristics of homeowners using interest-only mortgages. The table presents average partial effects and robust standard errors (in parentheses) from the probit estimation stated in Eq. (2). The dependent variable is a dummy variable indicating an IO mortgage. Household characteristics and regional and time fixed effects are also included. The table includes homeowners with a mortgage originated between 2004 and 2015. The origination year is used to represent the mortgage choice for each household.

	-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-
IAR, lag 1	0.124***	0.080***	0.040***	0.041***	0.038***	0.063***	0.113***	0.132***	0.293***
	(0.011)	(0.009)	(0.008)	(0.008)	(0.008)	(0.010)	(0.016)	(0.024)	(0.042)
DTA, lag 1	0.146***	0.119***	0.081***	0.071***	0.061***	0.070***	0.102***	0.103***	0.135***
	(0.008)	(0.007)	(0.006)	(0.005)	(0.006)	(0.007)	(0.013)	(0.020)	(0.040)
Log income, lag 1	-0.001	-0.001	0.007	0.021***	0.020***	-0.006	-0.053***	-0.044**	-0.050*
	(0.009)	(0.007)	(0.006)	(0.005)	(0.006)	(0.006)	(0.009)	(0.013)	(0.020)
Neg. income shock	0.035***	0.043***	0.048***	0.036***	0.046***	0.065***	0.067***	0.053***	0.111***
	(0.008)	(0.007)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.012)	(0.032)
Neg. income shock, lag 1	0.004	0.026***	0.025***	0.031***	0.028***	0.030***	0.021**	0.027**	-0.002
	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.010)	(0.023)
Inc. growth, 4 year	0.185***	0.153***	0.093**	0.108***	0.035	-0.144***	-0.208***	-0.092	0.135
	(0.044)	(0.036)	(0.032)	(0.031)	(0.031)	(0.028)	(0.042)	(0.084)	(0.119)
Observations	27,491	33,338	37,853	37,433	35,335	30,157	19,437	9,114	5,252
Pseudo R^2	0.139	0.116	0.083	0.073	0.067	0.070	0.085	0.093	0.099

Standard errors in parentheses

$^{*}(p < 0.05)$, $^{**}(p < 0.01)$, $^{***}(p < 0.001)$

Table 3: Characteristics of homeowners refinancing a repayment mortgage to an IO mortgage. The table presents average partial effects and robust standard errors (in parentheses) from the probit estimation stated in Eq. (3). The dependent variable is a dummy variable indicating if household i refinances a repayment mortgage to an IO mortgage. The regression controls for one-year lagged DTA, IAR, mortgage interest type, income, as well as the current level of education, gender, number of borrowers, number of kids and adults, household type, and regional and time fixed effects. Finally, as a control variable we include a dummy for a negative income shock of more than 10% (a dummy is included both for the year of action and the year before). The table includes homeowners with a repayment mortgage between 2003 and 2011. For households with a conversion from repayment mortgage to an IO mortgage, the household is represented by the conversion year. For households with no conversion, we use a random year to represent the mortgage choice for each household.

	By subperiod		Diff-in-Diff	
	2001-02	2003-06	Treatment	Control
CPI (2015=100)	77.48	82.38	78.38	78.38
Mortgage characteristics				
Loan amount	229.02	290.11	150.00	289.04
LTI	2.39	2.82	1.60	3.05
IO mortgage	-	0.23	-	-
FRM	0.97	0.79	0.97	0.93
Nom. interest rate (%)	7.33	5.69	7.19	6.64
Household characteristics				
Total debt	253.03	310.36	159.11	312.22
Debt to Asset ratio	0.34	0.33	0.21	0.43
Illiquid Asset Ratio	0.53	0.53	0.69	0.33
Income	102.42	108.64	100.07	99.14
Consumption	98.84	112.68	104.13	105.16
Consumption to Income	0.99	1.07	1.06	1.09
Number of borrowers	1.14	1.16	1.09	1.20
Avg. age (borrowers)	68.42	71.37	69.16	69.03
age: 60-64	0.36	0.12	0.29	0.29
age: 65-69	0.27	0.36	0.28	0.28
age: 70-	0.37	0.52	0.43	0.42
Single	0.42	0.45	0.44	0.44
Male	0.69	0.67	0.69	0.69
Number of adult residents	1.54	1.51	1.54	1.54
Number of kids	0.01	0.00	0.00	0.00
Education level 1	0.40	0.40	0.45	0.45
Education level 2	0.36	0.36	0.35	0.35
Education level 3	0.24	0.24	0.20	0.20
Region Copenhagen	0.19	0.21	0.20	0.20
Region Zealand	0.15	0.15	0.14	0.14
Region South Denmark	0.33	0.32	0.35	0.35
Region Middle Jutland	0.21	0.20	0.20	0.20
Region North Jutland	0.12	0.12	0.11	0.11
Observations	10,511	33,477	1,989	1,989

Table 4: Summary statistics for households above 60. The left panel displays the average values over the years related to the dominant mortgages for the two subperiods before and after the introduction of the IO mortgages in 2003. The right panel displays the values in 2002 for our control and treatment group used in the diff-in-diff estimation stated in Eq. (4). Loan amounts, debt, income, and consumption are in DKK 1,000, and measured as an average per adult in the household. See Section 2 for a more detailed description of variables.

	-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-
After intro of IO	0.061**	0.066***	0.095***	0.091***	0.029**	-0.015	-0.080***	-0.055**	-0.075***
	(0.024)	(0.018)	(0.012)	(0.012)	(0.010)	(0.013)	(0.016)	(0.017)	(0.016)
High IAR before IO intro	-0.008	0.006	-0.000	0.031*	0.000	-0.020	-0.037*	-0.027	0.022
	(0.026)	(0.021)	(0.014)	(0.013)	(0.011)	(0.015)	(0.018)	(0.018)	(0.016)
After intro of IO X High IAR before IO intro	0.052	0.041	0.009	-0.011	0.004	0.032	0.060**	0.072***	0.090***
	(0.032)	(0.022)	(0.016)	(0.015)	(0.013)	(0.018)	(0.022)	(0.021)	(0.018)
Observations	1,903	3,839	7,423	11,849	15,689	10,501	7,407	5,872	8,555
R^2	0.320	0.314	0.325	0.251	0.224	0.280	0.199	0.286	0.327

Standard errors in parentheses

$^{*}(p < 0.05)$,$^{**}(p < 0.01)$,$^{***}(p < 0.001)$

Table 5: Difference-in-difference estimation across age groups. The table presents the coefficients of interest from the difference-in-difference estimation of Eq. (4) that examines how the introduction of IO mortgages in late 2003 affects consumption for homeowners with a high illiquid asset ratio (IAR) relative to those with a low IAR. Each column includes only the subsample of households in that age group. Propensity matching is used to improve comparison between treatment and control groups. The matching is based on 2002-levels of FRM/ARM, income, debt-to-asset ratio, gender, household type, education, number of borrowers, number of kids and adults in household, and geographical region. Robust standard errors are used. Data used include homeowners from 2001 to 2006.

	-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-
After 2009	0.121***	0.091***	0.096***	0.049***	0.061***	0.020**	0.047***	0.121***	0.128***
	(0.014)	(0.009)	(0.006)	(0.006)	(0.005)	(0.006)	(0.008)	(0.010)	(0.007)
High IAR	-0.031	-0.045***	-0.030***	-0.042***	-0.019**	-0.020*	-0.018	0.050***	0.057***
	(0.018)	(0.012)	(0.009)	(0.011)	(0.007)	(0.008)	(0.009)	(0.012)	(0.009)
After 2009 X high IAR	-0.010	0.029*	0.020*	0.016*	-0.002	0.002	0.016	-0.005	-0.003
	(0.021)	(0.012)	(0.009)	(0.008)	(0.007)	(0.008)	(0.010)	(0.012)	(0.009)
Observations	5,244	13,403	28,147	37,701	46,893	49,052	37,916	25,052	32,902
R^2	0.265	0.278	0.321	0.273	0.244	0.212	0.202	0.232	0.316

Standard errors in parentheses

$^{*}\,(p < 0.05)\,,^{**}\,(p < 0.01)\,,^{***}\,(p < 0.001)$

Table 6: Placebo test of the difference-in-difference estimation. The table presents the coefficients of interest from a difference-in-difference estimation of an equation similar to Eq. (4) that examines how the financial crisis in 2009 affects consumption for homeowners with a high illiquid-asset ratio (IAR) relative to those with a low IAR. Each column includes only the subsample of households in that age group. Propensity matching is used to improve comparison between treatment and control group. The matching is based on 2007-levels of FRM/ARM, income, debt-to-asset ratio, gender, household type, education, number of borrowers, number of kids and adults in household, and geographical region. Robust standard errors are used. Data used include homeowners from 2006 to 2011.

	-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-
IO mortgage	0.024***	0.007***	-0.006***	-0.010***	-0.019***	-0.030***	-0.037***	-0.040***	-0.034***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)
FRM	0.014***	0.009***	0.006***	0.014***	0.018***	0.023***	0.011***	-0.003	0.007
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.005)
FRM × IO mortgage	0.004	0.005	0.008**	-0.005	-0.012***	-0.014***	-0.009**	0.008	-0.010*
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Observations	58,913	44,319	45,797	44,227	39,854	36,207	29,585	20,606	24,011
R^2	0.308	0.305	0.277	0.231	0.209	0.167	0.144	0.122	0.081
Adjusted R^2	0.307	0.304	0.276	0.231	0.208	0.167	0.143	0.121	0.080

Standard errors in parentheses

$^{*}\,(p < 0.05)\,,^{**}\,(p < 0.01)\,,^{***}\,(p < 0.001)$

Table 7: Other debt over total debt. The table presents coefficients and robust standard errors (in parentheses) from the OLS estimation stated in Eq. (5) across age groups. The dependent variable is the fraction of other debt relative to total debt. The regression controls for income, debt-to-asset ratio, gender, education level, number of borrowers, numbers of kids and adults and families represented in the household, and regional and time fixed effects are also included. The table includes homeowners with a mortgage between 2003 and 2015. A random year is used to represent the mortgage choice for each household.

	-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-
Panel A: Probit, Stock Market Participation									
IO mortgage	-0.015***	-0.013*	0.003	0.030***	0.039***	0.056***	0.058***	0.059***	0.045***
	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.008)	(0.008)
Observations	58,913	44,319	45,797	44,227	39,854	36,207	29,585	20,606	24,011
Pseudo-R^2	0.047	0.060	0.065	0.067	0.063	0.058	0.049	0.055	0.055
Panel B: Probit, Private Pension Participation									
IO mortgage	-0.028***	-0.013*	-0.012*	0.001	0.013*	0.024***	0.016**	0.003	
	(0.004)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	
Observations	58,913	44,319	45,797	44,227	39,854	36,207	29,585	20,606	
Pseudo-R^2	0.065	0.054	0.055	0.058	0.068	0.088	0.090	0.111	
Panel C: OLS, Pension contribution									
IO mortgage	-345.380	182.895	738.983	1893.912***	4761.639***	4089.196***	698.087	268.007	
	(245.916)	(374.718)	(418.785)	(495.030)	(630.413)	(717.831)	(711.320)	(528.053)	
FRM	1311.937***	1540.813***	513.802	413.091	-5.750	-746.665	531.835	-243.395	
	(236.522)	(343.953)	(382.043)	(468.561)	(439.127)	(597.423)	(677.082)	(459.421)	
FRM × IO mortgage	448.223	1235.544*	3081.585***	3909.618***	2441.985*	4548.786***	1572.829	1347.277*	
	(323.122)	(564.387)	(803.386)	(895.694)	(1055.682)	(1129.685)	(1079.918)	(606.182)	
Observations	58,913	44,319	45,797	44,227	39,854	36,207	29,585	20,606	
R^2	0.364	0.303	0.311	0.279	0.267	0.233	0.245	0.131	
Adjusted R^2	0.363	0.302	0.310	0.278	0.266	0.233	0.245	0.130	

Standard errors in parentheses

* $(p < 0.05)$,** $(p < 0.01)$,*** $(p < 0.001)$

Table 8: Asset diversification. The table presents coefficients (OLS), average partial effects (probit) and robust standard errors (in parentheses) from the probit and OLS estimations stated in Eqs. (6) and (5), respectively, across age groups. The dependent variable in Panel A is a dummy variable indicating whether or not the homeowner invests in bonds and stocks. In Panel B the dependent variable is a dummy variable indicating whether or not the homeowner contributes to a private pension saving account. In Panel C the dependent variable is the average pension contribution per adult in the household. The regression controls for income, debt-to-asset ratio, gender, education level, number of borrowers, numbers of kids and adults and families represented in the household, and regional and time fixed effects are also included. The table includes homeowners with a mortgage between 2003 and 2015. A random year is used to represent the mortgage choice for each household. Households above 70 are ignored in the analysis of pension contributions.

Internet Appendix

How do Interest-only Mortgages Affect Consumption and Saving over the Life Cycle?

This appendix describes some additional analyses only briefly mentioned in the main text.

IA.1 Data

Table 1 summarizes key data details by period or by contract type, but not by type *and* period. In particular, the type and period before and after the financial crisis could be of interest. Hence, Table IA.1 provides summary statistics by mortgage type and three years before and after 2009. We see a similar pattern in more or less all variables for the two types of mortgages in the periods around the financial crisis.

To show that our data are representative for Danish homeowners, Table IA.2 summarizes key household characteristics for all Danish homeowners for the same four sub-periods as in Table 1. We find that, on average, the homeowners of our sample are slightly older than the full Danish population of homeowners. Our sample has a smaller fraction of households below 34 compared to the full Danish population of homeowners, but a larger fraction of households in the age group 45-49. For the older age groups, the two distributions are similar. The difference in the age-levels is also reflected in several of the other household characteristics. For example, we see a lower total debt level in our sample, a lower consumption level, a higher income, higher pension contributions, etc. Regarding education level and the distribution across geographical regions, our sample is similar to the full sample of all Danish homeowners. Overall, we see no reason to believe that our sample is not representative of all Danish mortgage holders.

Looking at households entering the mortgage market in the 2004–2015 period, we see the same overall picture as for all households in our sample. This is illustrated in Figure IA.1 which shows the age-distribution of households' choice of mortgage. The dark [light] gray part of each column illustrates the fraction of households for the given age group entering into a repayment [IO] mortgage. Again we see that IO mortgages are most popular among young and old households.

Figure IA.2 shows for each of nine age groups the share of all homeowners with a mortgage shifting their dominant mortgage from a repayment mortgage to an IO mortgage (dark gray) or vice versa (light gray area). The remaining homeowners do not change their mortgage type. The

values in 2014 and 2015 for the youngest homeowners are over-estimated due to sample selection.[37] However, the relative size of the two columns is correct. Overall, we see that less than 6% of our sample shifts their dominant mortgage type in a given year. The fraction of households changing their dominant mortgage varies quite a lot over the business cycle. Intuitively, very few household changed their mortgage type in the first years after the introduction of IO mortgages, whereas we see more activity from 2010 and forward. The first years we see that more households replace a repayment with an IO mortgage, whereas in the latest years more households have changed their dominant mortgage from an IO mortgage to a repayment. This pattern can be explained by two observations. First, 2014 and 2015 are the first years where the IO-period for the very first IO mortgages run out. Second, interest rates are very low in Denmark as seen in Figure 2, which makes it more affordable for households to pay down their mortgage debt.

We exclude households with self-employed individuals as is standard in the literature, due to their unstable income-tax conditions and the difficulties in measuring the value of their business. Interestingly, we do not see a difference in the fraction of IO mortgages between households with at least one self-employed individual and households with no self-employed individuals in all the years from 2003 to 2015, cf. Table IA.3.

IA.2 Life-cycle patterns

Ideally, we would like to compare observed life-cycle profiles of households with an IO mortgages to households with repayment mortgages. Due to the time-span of our data this is not possible. Inspired by Betermier et al. (2017), we sort households by birth year into different cohorts using balanced data, and then estimate the life-cycle profile of the two different types of households. In particular, using balanced data on homeowners after the introduction of IO mortgages in Q4 of 2003, we follow around 24,000 households' consumption over the 12-year period from 2004 to 2015. Based on the age in 2004, we allocate each homeowner to one of nine age groups: below 35 years, 35-39, 40-44, ..., 65-69, and 70+ years. For each age group we estimate a polynomial relation between age and consumption per adult as illustrated in Figure IA.3 by the dashed lines. We then fit a polynomial to represent the overall consumption pattern across age groups which

[37] Our sample from the major mortgage bank ends in 2013. From the data including all mortgage banks we can track the customers in 2014 and 2015. However, new customers in the mortgage bank from 2014 and 2015 will not be included in our sample, and hence the total share of homeowners shifting their mortgage will be over estimated. Note, this sample selection does not affect any of our main results. When analysing the youngest households (where we typically also see most new homeowners) we include the expected future income growth measured over 7 years in our regressions and, hence, new young homeowners in the last years of our sample are not included. When analysing the older households we only look at existing homeowners and, hence, our results here are unaffected by the missing new homeowners in 2014 and 2015.

is illustrated by the solid dark line (households with a repayment mortgage) and the solid gray line (households with an IO mortgage). Figure IA.3 shows that the overall life-cycle consumption pattern has the hump shape well known from the US and other countries (Browning and Crossley, 2001; Gourinchas and Parker, 2002). The main innovation in Figure IA.3 is that we estimate separate consumption profiles for households with IO mortgages and households with repayment mortgages. We find that, across all age groups, homeowners with an IO mortgage tend to consume more than homeowners with a repayment mortgage.

IA.3 Extra robustness tests

Table 2 in the main text shows the results of a probit estimation of Eq. (2) with the dependent variable being a dummy indicator for an IO mortgage. As a robustness check, Table IA.4 lists the results of an OLS estimation. We observe that the two methods generate almost identical estimates of each coefficient. Based on a year-by-year OLS estimation of Eq. (2), Figure IA.4 shows the average partial effects of holding an IO mortgage in different age groups in the years 2004, 2009, and 2014. Comparing this with the results from the corresponding probit estimation in Figure 6, we see only tiny differences. Hence, the probit estimation and the OLS estimation lead to the same conclusions.

Next, we turn to the effect of income growth on the decision to take an IO mortgage, i.e., an estimation of Eq. (2) with income growth over h years added as an explanatory variable. For the case where income growth is measured over $h = 7$ years, Figure IA.5 shows the OLS-based average partial effects of income growth on IO mortgage choice across age groups. The results are very similar to the probit-based effects shown in Figure 8. Again, the probit estimation and the OLS estimation lead to the same conclusions.

IA.4 Extra analysis

Using an alternative measure of permanent income, Cocco (2013) obtains a measure of the risk in the permanent income of borrowers in different education and occupation groups. Cocco finds that groups with higher variance in permanent income shocks are less likely to choose an IO mortgage. Inspired by these results we rerun the probit estimation stated in Eq. (2) with income growth and income growth volatility added to the list of explanatory variables. The income growth volatility is based on the measure from Haurin (1991), who argues that income volatility can be estimated by taking the standard deviation of the income growth over the last years h and divide

that by the mean of the income growth rate over the last h years. To be consistent with our measure of income growth rate we use $h = 7$ years.

Panel a of Figure IA.8 shows the average partial effect of income growth measured over 7 years on the likelihood of having an IO mortgage across the different age groups, whereas Panel b shows the average partial effect of income growth volatility. Comparing Panel a to Figure 6 we see a small drop in the significance of the income growth rate.[38] As also noted by Cocco (2013) there is a high collinearity between the income risk measure and the income growth rate and, hence, the statistical significance of these variables is reduced when including both in the regression. Panel B shows that the income volatility is positively correlated with the probability of having an IO mortgage for the young and middle-aged households, whereas it is insignificant for the older households.

Finally, Figure IA.9 shows the parallel trend analysis that justifies the difference-in-difference estimation in Section 3.4, and Table IA.5 shows the results of two extra difference-in-difference regressions testing the effect of the introduction of IOs on the stock market participation in Panel A and risky asset share in Panel B as discussed in Section 4.2.

[38]Note that Panel A is directly comparable to Figure 6, the only difference is that we have added the income growth volatility to the list of explanatory variables.

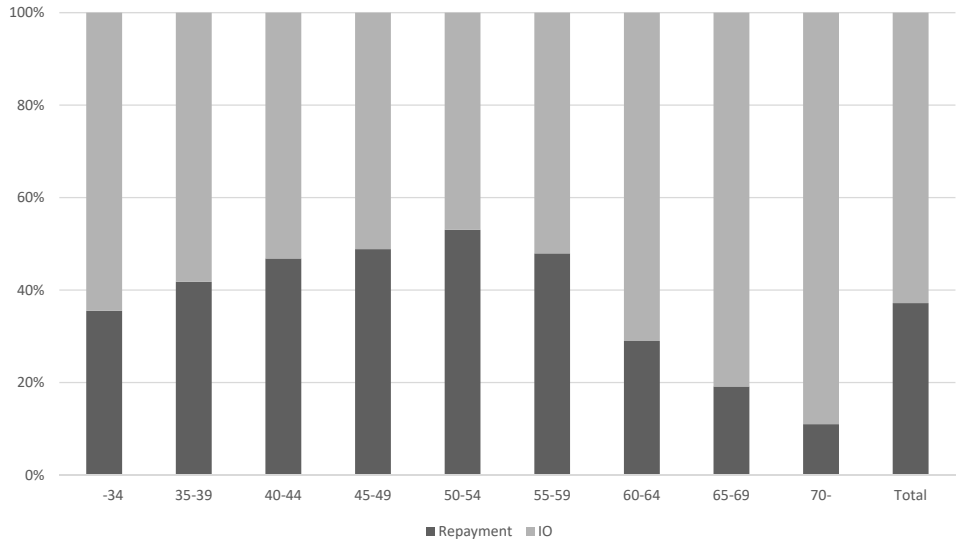

Figure IA.1: Type of mortgage when entering the mortgage market. The diagram shows for each age group the choice of mortgage type of households entering the mortgage market. The dark [light] gray part of each column represents the fraction of households entering into a repayment [IO] mortgage. A household is defined as entering into the mortgage market if the household has no mortgage debt in the two years prior to the entry. Based on data from the period 2004–2015.

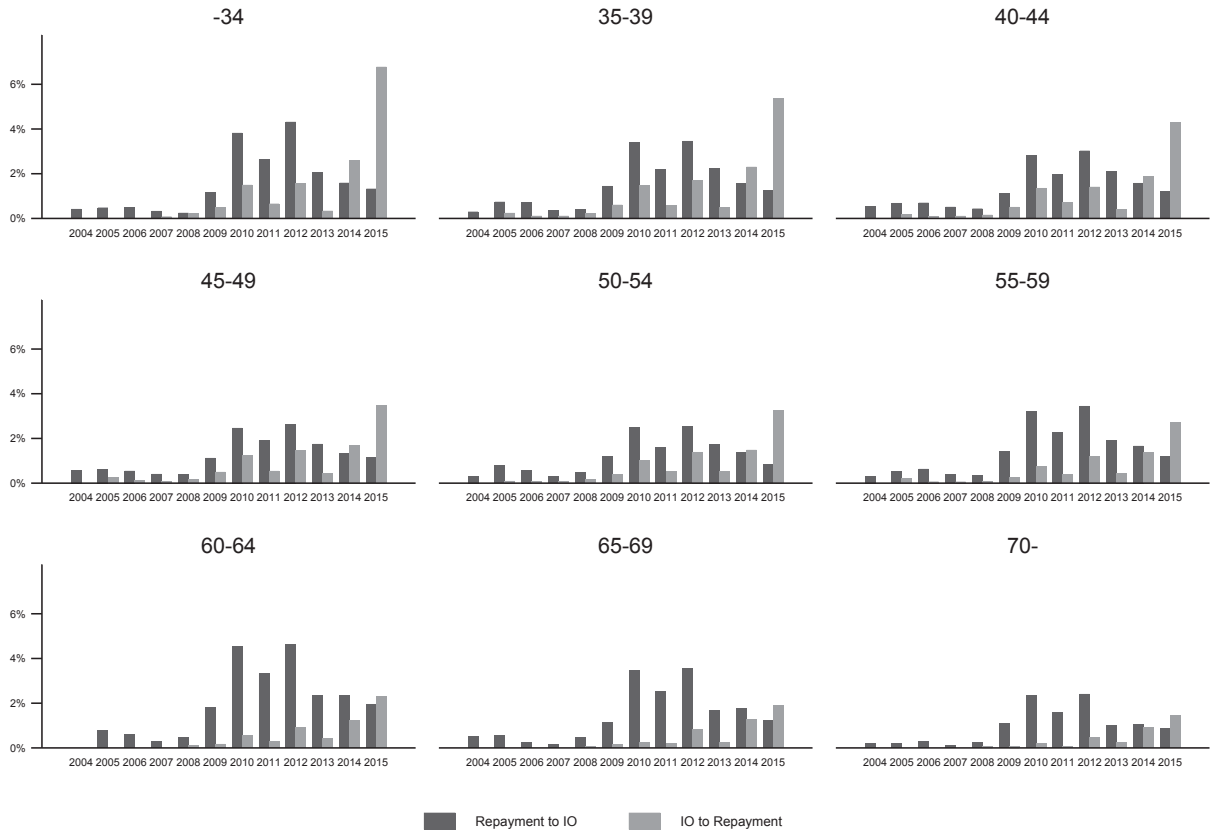

Figure IA.2: Shift in dominant mortgage type across age and years. The figure shows for each age group the share of all homeowners with a mortgage shifting their dominant mortgage from a repayment mortgage to an IO mortgage (dark gray columns) or vice versa (light gray column). The remaining homeowners do not change their mortgage type. The values in 2014 and 2015 for the youngest homeowners are over-estimated due to sample selection, cf. the explanation in footnote 37.

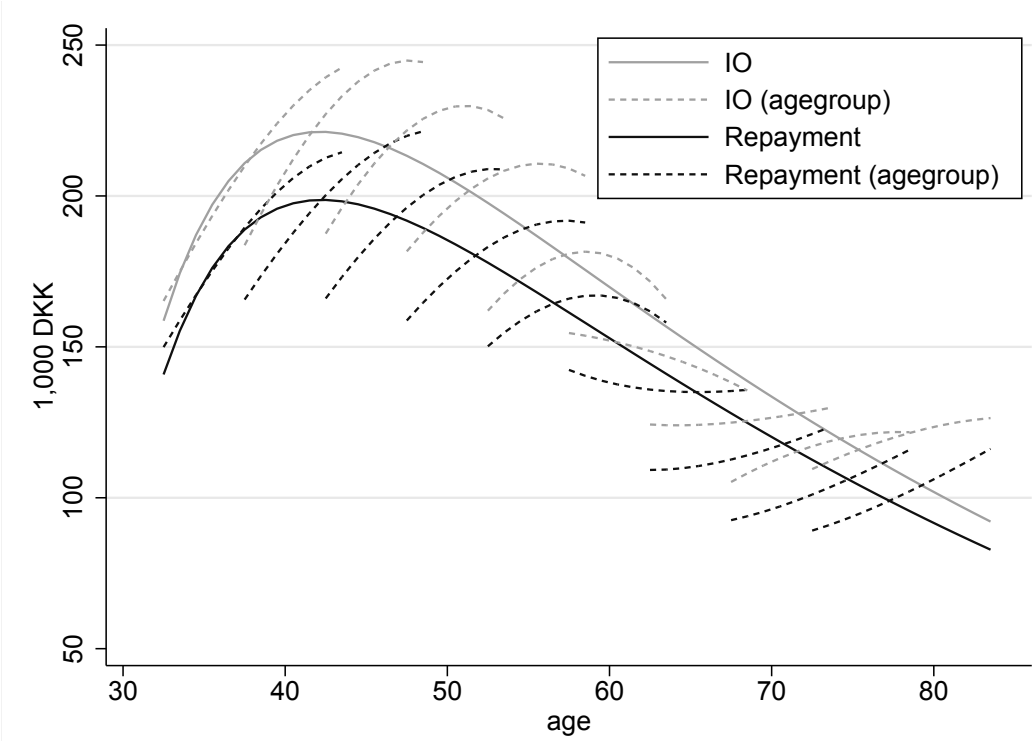

Figure IA.3: Consumption patterns over the life cycle. The graph shows median consumption from 2004 to 2015 for different age groups and across mortgage types. Consumption is measured as an average per adult in the household. The figure presents a polynomial fit for each age group (dashed line) and an overall polynomial fit of all age groups (solid line). Nine different age groups are used; below 35, 35-39, 40-44, ..., 65-69, and 70+ in 2004. Each observation for an age group is illustrated at the average age in that group. The gray curves are based on homeowners holding an IO mortgage at some point within the period from 2004 to 2015, whereas the black curves are based on homeowners holding only repayment mortgages within this time period. The graph applies balanced data on homeowners from 2004 to 2015.

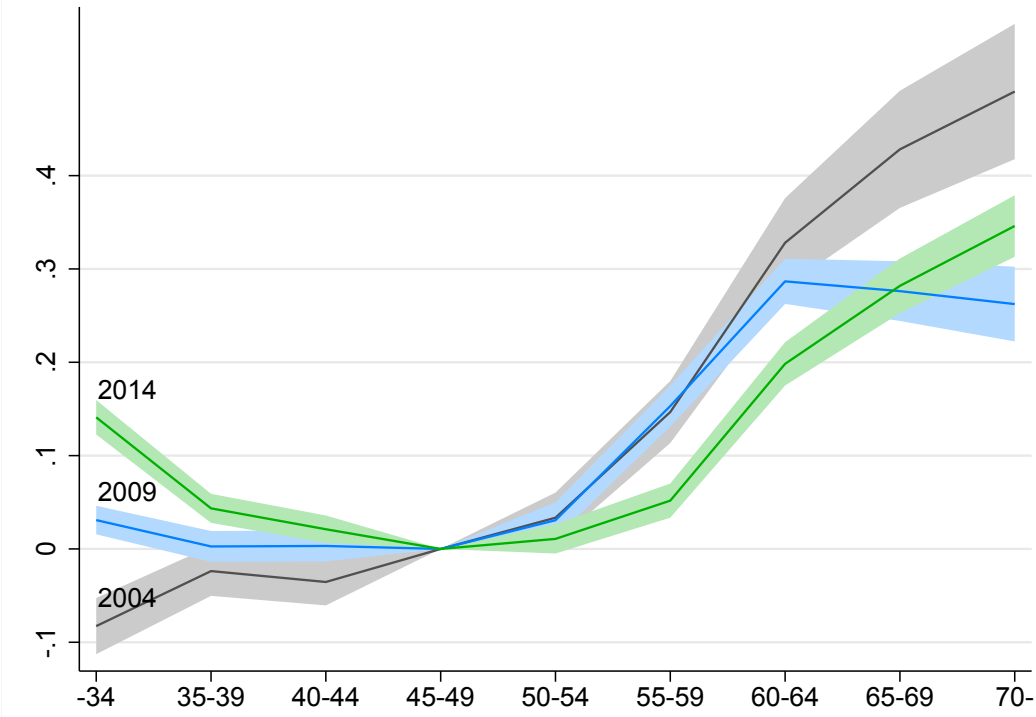

Figure IA.4: OLS robustness check of the probit estimation in Figure 6. The graphs depict the partial effects (solid lines) of holding an IO mortgage across age groups in year 2004, 2009, and 2014. The shaded areas illustrate the 95% confidence intervals. The partial effects follow from the OLS estimation testing the robustness of the probit estimation stated in Eq. (2), where the dependent variable is a dummy indicating an IO mortgage. The origination year is used to represent the mortgage choice for each household.

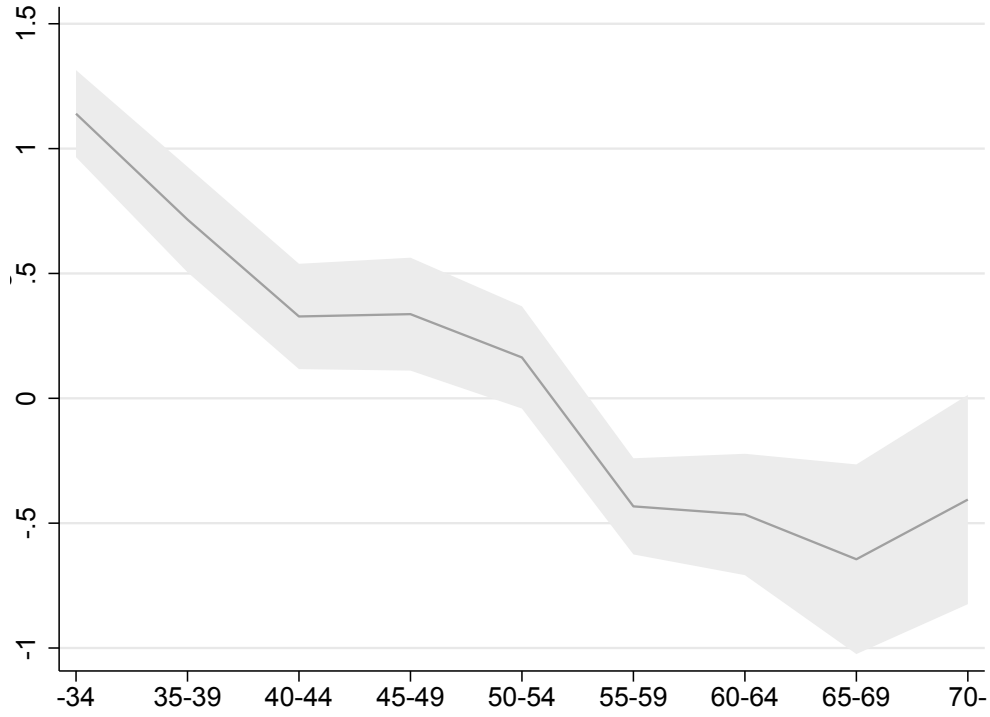

Figure IA.5: OLS robustness check of the probit estimation in Figure 8. The figure presents partial effects (solid line) of income growth with $h = 7$ for each age group from the OLS estimation testing the robustness of the probit estimation stated in Eq. (2) with the income growth rate added to the list of explanatory variables. The shaded area display the 95% confidence interval.

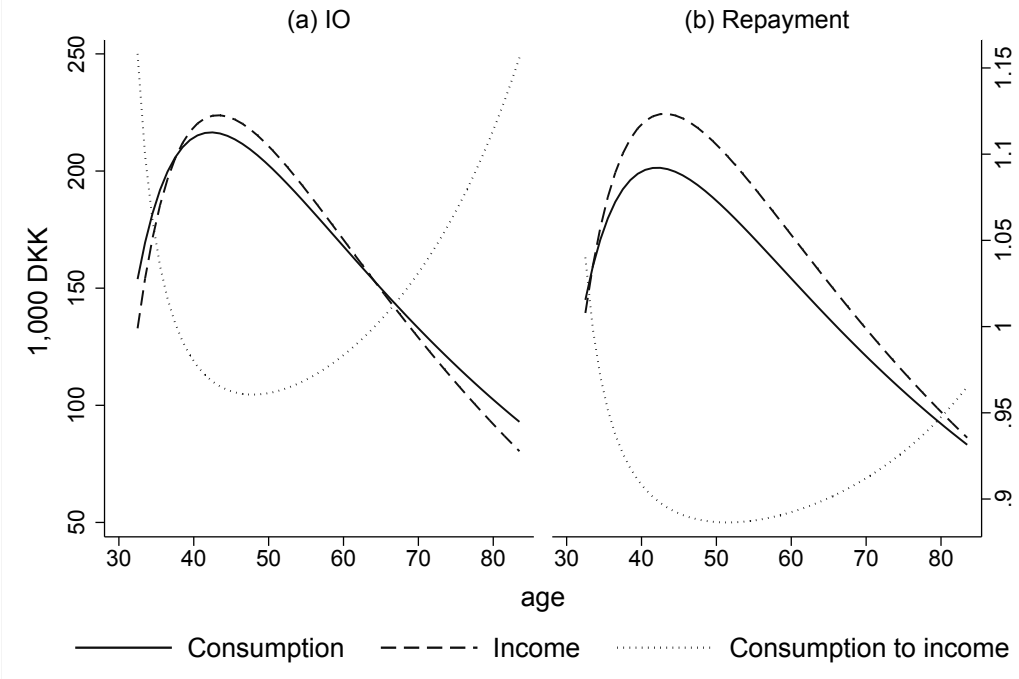

Figure IA.6: Consumption and income patterns over the life cycle. The graph presents median of annual consumption (solid line), annual income (dashed line), and the consumption-to-income ratio (dotted line; right-hand axis) over the life cycle. Consumption and income are measured as an average per adult in the household. Panel A is based on homeowners holding an IO mortgage at some point within the period from 2004 to 2015, whereas Panel B is based on homeowners holding only repayment mortgages within this time period. The graphs are generated by polynomial fits of nine age groups defined as: below 35, 35-39, 40-44, ..., 65-69, and 70+ in 2004. Each observation for an age group is illustrated at the average age in that group. The graph applies semi-balanced data on homeowners from 2004 to 2015 which we have data on for at least 10 years.

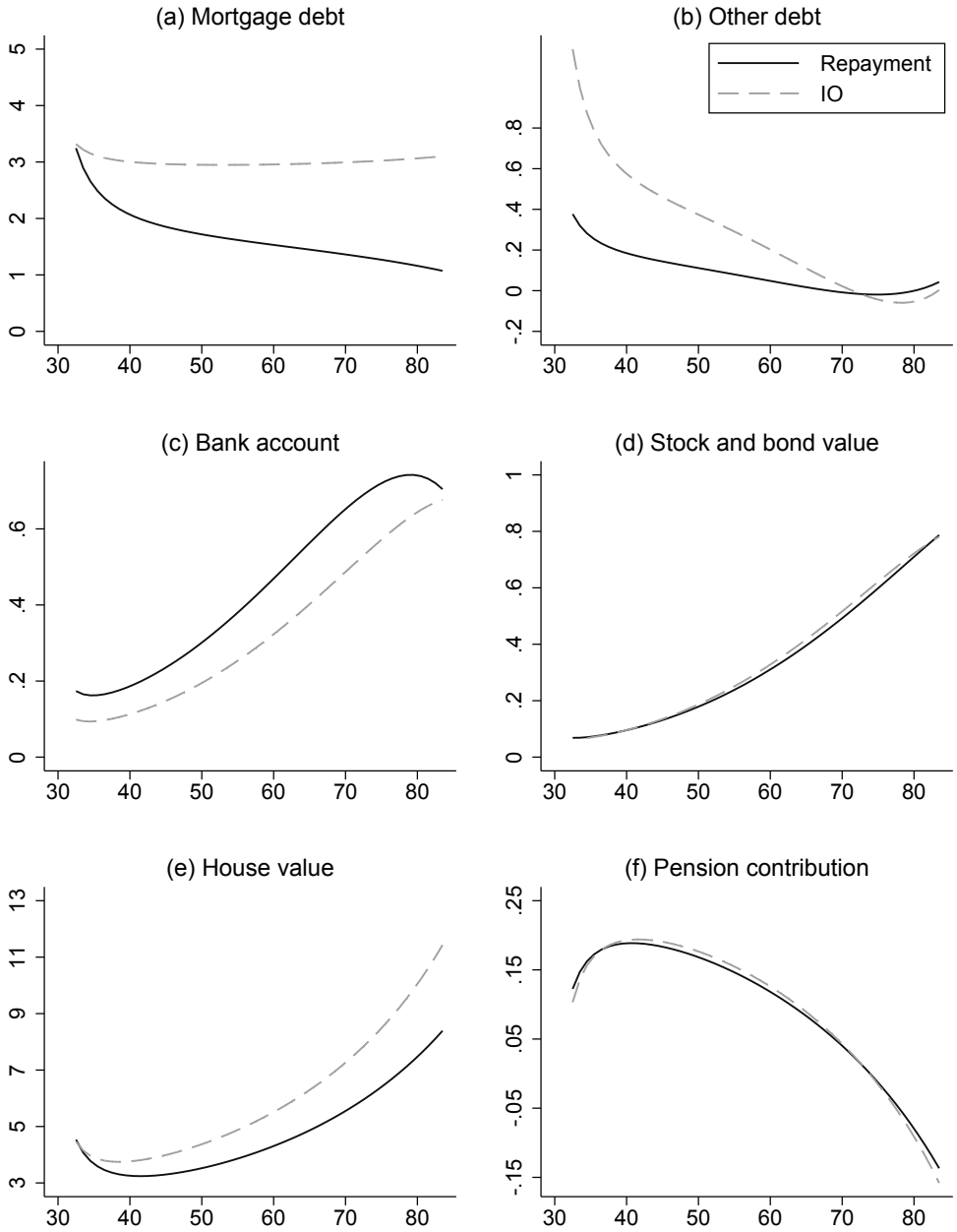

Figure IA.7: Life-cycle patterns for different financial variables relative to income. The graphs depict medians of mortgage debt, other debt, bank account, public house value, and pension contributions, as well as means of market value of stocks and bonds, from 2004 to 2015 for different age groups and across mortgage type. All variables are measured relative to annual income. The graphs show an overall polynomial fit of all the age groups. Nine age groups are used; below 35, 35-39, 40-44, ..., 65-69, 70 and above in 2004. Each observation for an age group is illustrated at the average age in that group. The dashed curves are based on homeowners holding an IO mortgage at some point within the period from 2004 to 2015, whereas the solid curves are based on homeowners holding only repayment mortgages within this time period. The graph applies semi-balanced data on homeowners from 2004 to 2015 which we have data on for at least 10 years.

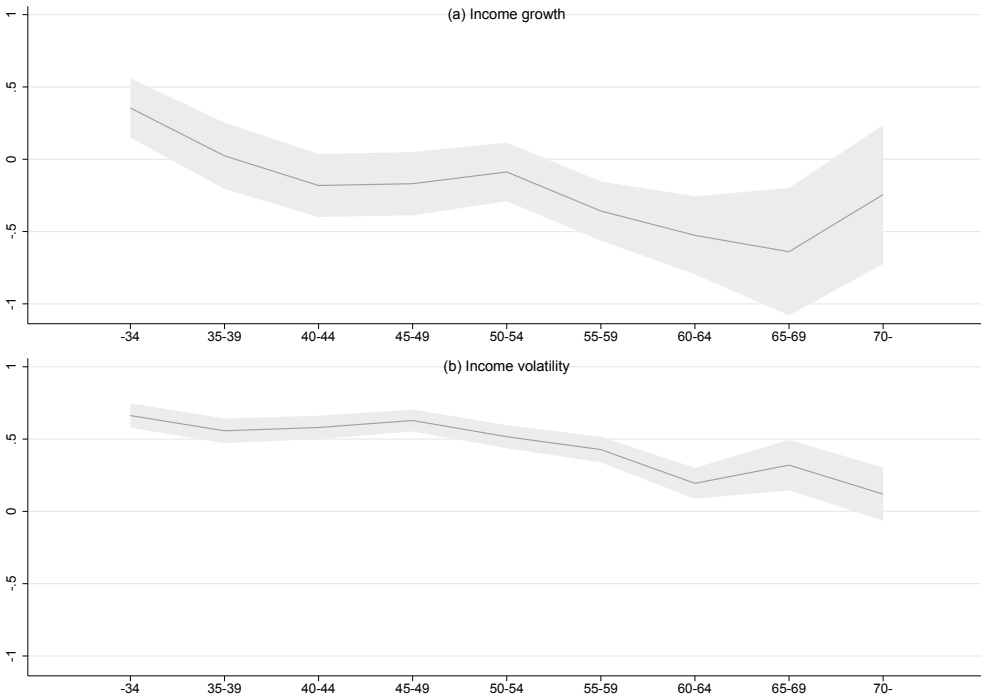

Figure IA.8: Average partial effects of income growth and volatility across age groups, respectively. The solid line in the top [bottom] panel presents average partial effects of income growth [income volatility] from the probit estimation stated in Eq. (2) with the income growth rate and income growth volatility added to the list of explanatory variables. The shaded area displays the 95% confidence interval.

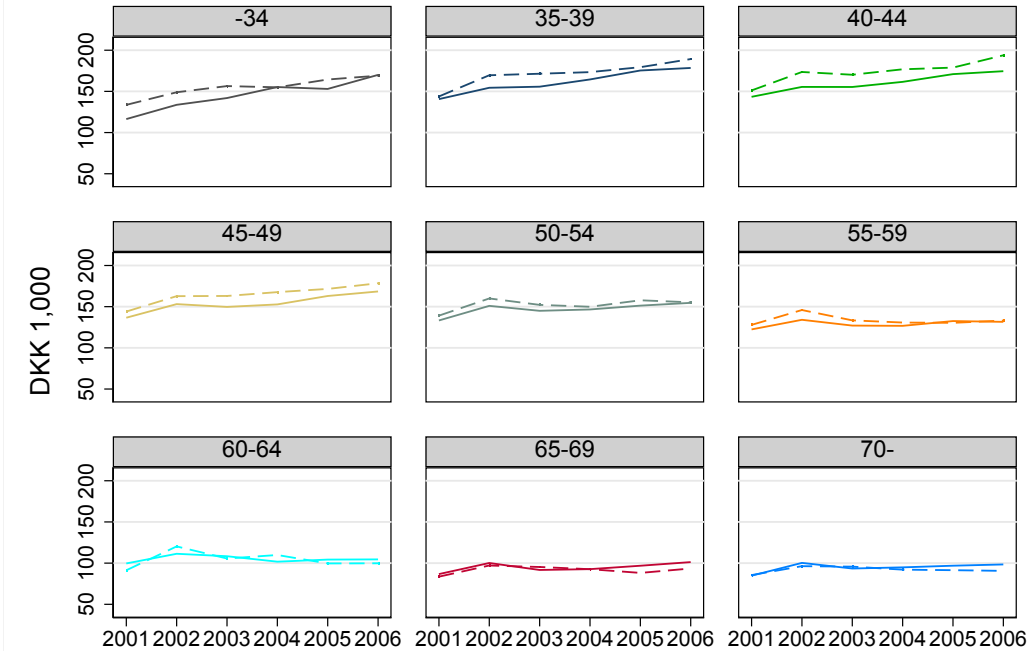

Figure IA.9: Parallel trend analysis. The graph presents the average annual imputed consumption in thousand DKK for homeowners with high (solid) and low (dashed) illiquid asset ratio over the period from 2001 to 2006. An illiquid asset ratio above [below] 50% is referred to as 'high' ['low']. The analysis is based on homeowners from 2001 to 2006.

	IO		Repayment	
	2006-08	2009-11	2006-08	2009-11
CPI (2015=100)	85.96	91.95	85.96	91.95
Mortgage characteristics				
Total loan amount	692.56	807.02	481.09	586.99
LTI	4.38	4.39	2.66	2.84
At least one IO	1.00	1.00	0.02	0.05
Actual IO period	0.98	0.95	0.00	0.00
FRM	0.29	0.22	0.66	0.60
Nom. interest rate (%)	4.67	2.76	4.97	3.73
Household characteristics				
Total debt	855.65	987.50	546.26	632.13
Debt to Asset ratio	0.78	1.00	0.59	0.72
Income	164.80	192.87	185.83	211.56
Consumption	179.93	195.90	177.27	195.68
Consumption to Income	1.14	1.06	0.97	0.94
Pension contribution	31.12	34.37	34.79	39.53
Number of borrowers	1.51	1.64	1.49	1.64
Avg. age (borrowers)	50.05	48.66	48.49	48.26
age: -34	0.17	0.21	0.13	0.13
age: 35-39	0.12	0.13	0.13	0.13
age: 40-44	0.12	0.12	0.15	0.15
age: 45-49	0.10	0.10	0.15	0.15
age: 50-54	0.09	0.09	0.15	0.14
age: 55-59	0.10	0.09	0.13	0.13
age: 60-64	0.12	0.10	0.08	0.08
age: 65-69	0.08	0.08	0.04	0.04
age: 70-	0.09	0.09	0.05	0.04
Single	0.21	0.20	0.17	0.16
Household with several families	0.05	0.05	0.05	0.05
Couple	0.74	0.75	0.78	0.79
Male	0.86	0.87	0.91	0.92
Number of adult	1.77	1.78	1.82	1.82
Number of kids	0.85	0.90	0.91	0.93
Education level 1	0.13	0.11	0.12	0.10
Education level 2	0.46	0.44	0.45	0.45
Education level 3	0.41	0.45	0.42	0.45
Region Copenhagen	0.23	0.19	0.16	0.13
Region Zealand	0.17	0.16	0.13	0.13
Region South Denmark	0.25	0.25	0.30	0.29
Region Middle Jutland	0.22	0.26	0.25	0.28
Region North Jutland	0.13	0.14	0.15	0.17
Observations	130,739	354,056	323,900	511,400

Table IA.1: Summary statistics by mortgage type. The table presents average values over the three years before and after 2009, respectively, related to the dominant mortgages. Loan amounts, debt, income, and consumption are in DKK 1,000, and measured as an average per adult in the household. The left gray panel displays the average values for households with an IO mortgage for the two three-year subperiods before and after 2009. The right panel displays the average values for households with a repayment mortgage for the two three-year subperiods before and after 2010.

	2001-02	2003-06	2007-10	2011-15
CPI (2015=100)	77.48	82.38	88.90	97.64
Household characteristics				
Total debt	497.38	656.80	878.10	951.52
Debt to Asset ratio	0.74	0.76	0.77	0.88
Income	141.03	162.08	182.76	215.98
Consumption	169.70	212.05	222.18	226.77
Consumption to Income	1.21	1.33	1.23	1.06
Pension contribution	19.34	26.16	33.57	32.78
Avg. age (borrowers)	46.47	46.47	47.21	49.08
age: -34	0.23	0.22	0.20	0.15
age: 35-39	0.17	0.17	0.17	0.16
age: 40-44	0.13	0.14	0.15	0.15
age: 45-49	0.09	0.09	0.09	0.10
age: 50-54	0.10	0.09	0.09	0.09
age: 55-59	0.10	0.11	0.10	0.09
age: 60-64	0.07	0.08	0.09	0.09
age: 65-69	0.05	0.05	0.05	0.08
age: 70-	0.07	0.06	0.07	0.09
Single	0.20	0.20	0.21	0.22
Household with several families	0.09	0.09	0.08	0.09
Couple	0.71	0.71	0.71	0.69
Male	0.89	0.89	0.89	0.88
Number of adult residents	1.86	1.85	1.85	1.86
Number of kids	0.77	0.80	0.82	0.81
Education level 1	0.16	0.14	0.12	0.10
Education level 2	0.48	0.47	0.45	0.43
Education level 3	0.36	0.39	0.43	0.46
Region Copenhagen	0.25	0.25	0.25	0.25
Region Zealand	0.17	0.17	0.17	0.17
Region South D	0.23	0.23	0.23	0.23
Region Middle	0.24	0.23	0.23	0.23
Region North J	0.12	0.12	0.11	0.12
Observations	2,306,237	4,458,481	4,434,886	5,494,039

Table IA.2: Summary statistics for the full Danish population of homeowners. The table presents average values of household characteristics for the same four subperiods as in Table 1. Loan amounts, debt, income, and consumption are in DKK 1,000, and measured as an average per adult in the household. See Section 2 for a detailed description of the variables.

	2003	2004	2005	2006	2007	2008	2009
Not self-employed	0.04	0.11	0.18	0.25	0.29	0.33	0.38
Self-employed	0.04	0.11	0.17	0.24	0.29	0.33	0.39
Observations	38,328	49,441	78,677	151,132	174,648	248,668	344,603

	2010	2011	2012	2013	2014	2015
Not self-employed	0.43	0.45	0.48	0.52	0.52	0.50
Self-employed	0.44	0.46	0.50	0.53	0.53	0.51
Observations	371,643	372,883	377505	379,523	349,435	332,618

Table IA.3: Self-employment and the fraction of mortgages being IO. The table presents the fraction of mortgages that are of the IO type among households with at least one self-employed adult and among households with no self-employed adults.

	Coef	Robust SE
Age: -34	0.070***	(0.003)
Age: 35-39	0.010**	(0.003)
Age: 40-44	0.006*	(0.003)
Age: 50-54	0.015***	(0.003)
Age: 55-59	0.103***	(0.004)
Age: 60-64	0.234***	(0.005)
Age: 65-69	0.288***	(0.006)
Age: 70-	0.320***	(0.006)
FRM	-0.305***	(0.002)
Log bank account	-0.003***	(0.001)
Log income	-0.150***	(0.003)
Debt to Asset ratio	0.230***	(0.002)
Male	-0.049***	(0.004)
Education level 2	0.024***	(0.003)
Education level 3	0.038***	(0.003)
Number of borrowers	0.010***	(0.002)
Number of adult residents	-0.048***	(0.006)
Number of kids	0.014***	(0.001)
Single	0.022***	(0.006)
Observations	290,494	

Standard errors in parentheses

* $(p < 0.05)$,** $(p < 0.01)$,*** $(p < 0.001)$

Table IA.4: OLS robustness check of the probit estimation in Table 2. The table presents coefficients and robust standard errors (in parentheses) from OLS estimation testing the robustness of the probit estimation stated in Eq. (2). The dependent variable is a dummy variable indicating an IO mortgage. Household characteristics and regional and time fixed effects are also included. The table includes homeowners with a mortgage originated between 2004 and 2015. The origination year is used to represent the mortgage choice for each household.

	-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-
Panel A: Stock Market Participation									
After intro of IO	0.027	0.018	0.068	0.119***	0.019	0.120***	0.027	0.004	-0.034
	(0.090)	(0.063)	(0.043)	(0.035)	(0.029)	(0.036)	(0.045)	(0.052)	(0.041)
High IAR	-0.432***	-0.159*	-0.311***	-0.388***	-0.308***	-0.276***	-0.768***	-0.859***	-0.561***
	(0.100)	(0.071)	(0.053)	(0.040)	(0.034)	(0.042)	(0.050)	(0.055)	(0.046)
After intro of IO X High IAR	0.088	0.113	-0.025	0.006	0.035	0.017	-0.069	-0.066	-0.001
	(0.121)	(0.083)	(0.059)	(0.047)	(0.040)	(0.049)	(0.060)	(0.069)	(0.056)
Observations	1,983	3,964	7,721	12,436	16,518	11,025	7,777	6,126	8,753
Pseudo-R^2	0.092	0.083	0.060	0.081	0.056	0.077	0.130	0.149	0.092
Panel B: Risky asset share, RAS									
After intro of IO	0.030	0.031	0.031**	0.044***	0.012	0.037***	0.060***	0.048***	0.072***
	(0.029)	(0.017)	(0.012)	(0.009)	(0.007)	(0.010)	(0.010)	(0.011)	(0.008)
High IAR	0.073*	0.070***	0.072***	0.019	0.025**	0.007	0.004	0.079***	0.059***
	(0.033)	(0.019)	(0.013)	(0.010)	(0.008)	(0.010)	(0.010)	(0.011)	(0.008)
After intro of IO X High IAR	0.023	-0.006	-0.009	0.000	0.007	0.028*	-0.023	-0.014	-0.009
	(0.039)	(0.023)	(0.016)	(0.012)	(0.010)	(0.012)	(0.013)	(0.015)	(0.012)
Observations	698	1,903	3,603	6,142	8,529	5,777	4,024	2,431	3,515
Pseudo-R^2	0.137	0.078	0.069	0.050	0.061	0.094	0.082	0.173	0.112

Standard errors in parentheses

* $(p < 0.05)$,** $(p < 0.01)$,*** $(p < 0.001)$

Table IA.5: Difference-in-difference estimation across age groups. The table presents the coefficients of interest from two difference-in-difference estimations of an equation similar to Eq. (4), but with stock market participation as the dependent variable in Panel A and risky asset share as the dependent variable in Panel B. Propensity matching is used to improve comparison between treatment and control group. The matching is based on 2007-levels of FRM/ARM, income, debt-to-asset ratio, gender, household type, education, number of borrowers, number of kids and adults in household, and geographical region. Robust standard errors are used. Data used in Panel A includes homeowners from 2001 to 2006, whereas data used in Panel B includes homeowners which at some point in the period 2001-2006 has participated in the stock market.

Chapter 2

The end is near: Consumption and savings decisions at the end of interest-only periods

The end is near: Consumption and savings decisions at the end of interest-only periods

Rikke Sejer Nielsen

October 29, 2021

Abstract

Using Danish register-based household data on interest-only (IO) borrowers containing detailed information on their mortgages, we study the consumption behavior of IO borrowers around the end of IO periods, where amortization starts or a refinance takes place. We find a positive average consumption response when the borrower refinances to a new IO mortgage, whereas it is negative in response to starting amortization. For households with expiring IO mortgages, we show a significant variation in the consumption response across age and level of consumption during the IO period, indicating that consumption smoothing over the mortgage life depends on these borrower characteristics. Young borrowers use the extra liquidity in the IO period to repay bank debt, whereas others mostly tend to use it on consumption. At expiration, we find that either borrowing constraints *force* IO borrowers to start amortization rather than rollover to a new IO mortgage, or IO borrowers start amortization *voluntarily* to minimize the cost of debt. Our findings have implications for regulation of IO mortgages.

Keywords: Mortgage choice; micro data; consumption effects.

JEL subject codes: G11

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1 Introduction

Since the eruption of the financial crisis in 2007, interest-only (IO) mortgages have been heavily debated all over the world due to their riskiness compared to traditional mortgage products. IO mortgages provide extra liquidity for borrowers to consume or to save. The higher financial flexibility that IO mortgages offer raises a general concern about the ability of IO borrowers to plan consumption and saving. Prior literature on IO mortgages finds evidence for both good and bad life-cycle consumption planning among IO borrowers. Whereas Amromin, Huang, Sialm, and Zhong (2018), Piskorski and Tchistyi (2011), Cocco (2013), and Larsen, Munk, Nielsen, and Rangvid (2021) find evidence in support of sophisticated use of IO mortgages, where access to IO mortgages helps borrowers to better smooth consumption over the life cycle, several other studies (e.g., Laibson (1997), Amromin et al. (2018), Gathergood and Weber (2017), and Andersen, Bech, and Stefani (2020a)) show that IO borrowers do not manage to optimally plan consumption over the life cycle. Existing literature does not fully explain how household consumption and savings are affected around the end of the IO period, where amortization starts or a new IO period is initiated. Consumption and savings behavior around the end of the IO period is important for regulation of IO mortgages as it addresses central issues related to the use of IO mortgages, such as whether IO borrowers manage to plan consumption and savings during the IO period to maintain consumption after amortization starts, and how the leverage of IO borrowers changes when they rollover their IO mortgage to a new one. Using register-based panel data on Danish IO borrowers, we investigate these issues by exploring consumption and saving behavior around the end of IO periods. The data, which combines mortgage data and register-based data on socioeconomic variables, property data, and demographical data, covers all Danish borrowers from 2009 to 2018, but we also use household characteristics and socioeconomic variables dating back to 2003. The richness of our data allows us to investigate consumption and savings decisions, as well as mortgage choices during and after the IO period, for IO borrowers with IO mortgages originating between 2003 (introductory year of IO mortgages) and 2008. To investigate the consumption behavior around the end of the IO period, we apply an event study on the four years before and three years after the end of the IO period.

In Denmark, where the IO period is limited to 10 years, we find that IO borrowers tend to end the IO period before it expires. IO periods may end early due to refinancing (to a new IO mortgage or to a repayment mortgage), early amortization, or repayment of the IO mortgage. We find that IO borrowers typically end their current IO period with refinancing (mainly a new IO mortgage). This is not surprising as refinancing is relatively easy and a low-cost option upfront in Denmark. Strikingly, however, the refinancing tendency is completely opposite for IO borrowers that let the IO period expire, around 60% of them starting amortization, only 20% refinancing to a new mortgage, 15% divorcing or starting a new relationship, and 5% repaying the mortgage debt. We show that the mortgage choice at the end of the IO period depends on age, debt, mortgage type, income profile, stock market participation, and the region where the property is located.

We find that IO borrowers that refinance to a new IO mortgage before the IO period expires tend to consume more after refinancing, whereas those that refinance to a new IO mortgage at expiration consume the same after refinancing. On top of that we show that IO borrowers that refinance to new IO mortgages tend to take up more debt in the refinancing. In the short run, IO borrowers that refinance to a new IO mortgage thus seem to be better off, but over a longer perspective, this may not be the case. It is worrying that IO borrowers tend to increase mortgage debt when they rollover their current IO mortgage to a new one, as these more indebted IO borrowers are more likely to end in financial difficulties later on, everything else equal. However, the future financial situation of the IO borrowers depends on, for example, house price changes, interest rate movement, and saving and consumption during the IO period. Unfortunately, the timespan of our data does not allow us to investigate the second round of IO periods yet but doing so is worthwhile in the future.

In contrast to IO borrowers that refinance to a new IO mortgage, consumption and debt decisions of IO borrowers that refinance to a repayment mortgage are not worrying. When refinancing to a repayment mortgage, the average IO borrower only take on a bit more debt and consume the same fraction of income after refinancing compared to before refinancing. Results suggest that these IO borrowers succeed in starting amortization without cutting consumption persistently, which indicate that they are better off when refinancing.

For rational unconstrained IO borrowers that start amortization early or at the expiration of the current IO period, we expect the consumption to be unaffected around the beginning of the amortization period. The amortization is planned and anticipated for IO borrowers that let the IO period expire. Thus, as predicted by the permanent income hypothesis, the anticipated reduction in disposable income when amortization starts should not affect the consumption of rational unconstrained borrowers. For IO borrowers that start amortization early, no consumption response is expected, as the decision to start amortization early is voluntary. Against our expectations, we find that IO borrowers consume less after they start amortization, independent of whether the amortization starts early or at expiration. For the relatively few IO borrowers that start amortization early, the consumption reduction is not a major concern, as the amortization choice is voluntary. Early amortization may even reflect a tendency among IO borrowers trying to limit their consumption and increase savings by starting amortization early. On the other hand, for the IO borrowers that let the IO period expire, the amortization choice may be voluntary or forced by borrowing constraints. Thus, if forced, the consumption reduction at expiration is worrying, as it may reflect a lack of consumption smoothing over the life cycle of the mortgage.

To better understand the consumption behavior of IO borrowers with expiring IO mortgages, we explore the cross-sectional variation in the consumption behavior across borrower characteristics. We show that age and average consumption to one-year lagged income (CTI) during the IO period are key determinants for the consumption response to the anticipated disposable income decrease at expiration. Despite the fact that all IO borrowers experience an increase in mortgage payments

when the IO period expires, IO borrowers with a higher consumption level during the IO period reduce consumption more compared to those with a lower level. Across quartiles of average CTI during the IO period, we find a mortgage payment reduction between 7.2% and 10.6% of income, and a consumption response between -17.1% and 13.5% of income when the amortization period begins, implying a marginal propensity to consume (MPC) out the increase in mortgage payments between -186.8% and 161.2%. Regarding age, we find that borrowers above 40 years of age, measured at origination of the IO period, reduce consumption more than young IO borrowers, which we define as below 39 years of age. Young IO borrowers experience an increase in mortgage payments of 7.7% of income and a reduction in consumption of 2.8% when the amortization period begins. This corresponds to an MPC of 36.2%. For middle-aged (older) borrowers 40 to 54 years of age (above 55 years of age) at origination, the consumption response at the expiration of the IO period is -5.5% (-5.9%). On average, the mortgage payment increases by 8.0% for the middle-aged borrowers and 9.3% for the older borrowers when the amortization period starts; thus, the consumption response corresponds to an MPC of 69.0% and 63.1%, respectively.

We find the two determinants to be highly correlated, in the sense that the different age groups use the extra liquidity during the IO period for different saving and consumption purposes. This explains differences in consumption behavior around the expiration of the IO period. Young borrowers tend to use the saved repayments during the IO period to repay bank debt. Older borrowers instead use saved repayments on consumption or to increase bank holdings to consume after the IO period. In more detail, older borrowers with *low* average CTI during the IO period (below the 25^{th} percentile) tend to use saved repayment in the IO period to save more in their bank account, whereas the remaining older borrowers tend to use the saved repayments on consumption. In the amortization period, those with *low* average CTI during the IO period manage to increase consumption by withdrawing funds from their bank account, the remaining older borrowers all reduce consumption. Middle-aged households tend to be driven by a mixture of the two but at a lower scale. Across all age groups, however, for IO borrowers that consume the most during the IO period, saved repayments in the IO period serve no other purpose than to increase consumption. Thus, consumption is hurt more in these households when the IO period runs out. The tendency is more common among middle-aged and older borrowers, which explains why they are more exposed to the expiration of the IO period, on average, relative to the young borrowers.

In our analysis, average CTI during the IO period is used to reflect how the IO borrowers apply the extra liquidity in the IO period (for savings or for consumption). Some may argue that consumption and saving decisions in the IO period inherently drive the level of consumption in the amortization period. The argument is based on the belief that higher current consumption (during the IO period) lowers future consumption. This is indeed the case in the long run. But, in the short run, which we are examining here, this is not necessarily the case. Even if a borrower chooses to consume a high fraction of income during the IO period, the borrowers may potentially maintain consumption in the amortization period by taking on new debt, selling stocks and bonds,

withdrawing liquid funds from their bank holdings, or by income growth. Thus, the consumption level during the IO period does not drive the consumption behavior when the IO period expires but is instead an indicator of how IO borrowers apply the extra liquidity during the IO period.

Keeping the IO mortgage until the IO period expires and starting amortization may be a voluntary or forced decision by the IO borrowers, who may have the incentive to start amortization to build up home equity, avoid future borrowing constraints, or reduce the cost of debt. The last mentioned seems to be the case for young IO borrowers. We find evidence indicating that young IO borrowers use the IO period to repay bank debt, which means that the IO mortgage is thus used as part of a repayment plan that minimizes the cost of debt while keeping debt payments stable. Evidence also indicates that middle-aged and older borrowers voluntarily choose to repay toward their mortgage to save on the cost of debt. The loan-to-value ratio (LTV) hovers around 60% for middle-aged borrowers that refinance to an IO mortgage, and around 40% for older borrowers that refinance to an IO mortgage. Relative to borrowers that refinance to an IO mortgage, LTV for middle-aged and older borrowers that start amortization at expiration is, on average, higher. Thus, the LTV for borrowers that actually choose to refinance to a new IO mortgage reaches one of two cutoff points (40% and 60%), for which mortgage contribution fees are lowered. On the matter of borrowing constraints, we find that LTV clearly affects the refinancing tendencies for middle-aged and older borrowers. A lower fraction of borrowers that refinance to a new IO mortgage at expiration have an LTV above 80% just prior to the refinancing, relative to those that refinance to a repayment mortgage or start amortization. Average LTV is also relatively lower for borrowers that refinance to a new IO mortgage. These results support the fact that some IO borrowers start amortization because their borrowing is constrained and cannot be granted for a new IO mortgage. As Andersen et al. (2020a) point out, borrowing constraints may explain the negative consumption response at the expiration of the IO period for a rational IO borrower, if the borrowing constraints are unexpected.

Our findings are useful for regulatory purposes for two reasons. First, young borrowers that want to use the IO period to repay bank debt are more likely to keep the IO mortgage throughout the IO period and start amortization at expiration. At expiration, their consumption is not hurt either, implying that they indeed manage to smooth consumption over the life cycle of the mortgage. Additionally, when the IO period is used to repay bank debt, cost of debt is reduced over the life cycle, everything else equal. The opposite is the case for young borrowers that consume a high fraction of saved repayments, i.e., they fail to smooth consumption at expiration. As banks are able to track and plan repayments on bank debt, the granting process of IO mortgages could optimally depend on whether the young borrowers plan to use the saved repayments on repaying bank debt or not. Second, for middle-aged and older households, our results points to the fact that regulation may be needed for borrowers with low home equity. Banks at least need to advise borrowers about possible future borrowing constraints, or help borrowers to commit to increasing their bank holdings or other liquid holdings during the IO period to cover the increase mortgage

payments after the IO period.

A recent paper by Andersen et al. (2020a) also explores consumption behavior of Danish IO borrowers at expiration of the IO period. Using Danish mortgage data like ours, they show that the average IO borrower reduces consumption by 3% of income in response to an increase in mortgage payments of 9% of income when the IO period expires. Similar to Andersen et al. (2020a) we investigate consumption patterns and mortgage choices at the expiration, but we also repeat the analysis around the end of IO periods lasting 6, 7, and 8 years. This is relevant, as refinancing is common in Denmark. Furthermore, at expiration, we also use the setting to examine cross-sectional variation in consumption behavior across borrower characteristics. In response to the reduction in the anticipated disposable income at expiration, we indeed find that the consumption response varies across the age and level of CTI of IO borrowers during the IO period. For the average IO borrower, we find results similar to Andersen et al. (2020a).

Our study also relates to other literature on the usage of IO mortgages and the characteristics of IO borrowers. We contribute to this line topic by exploring consumption patterns at the end of the IO period across borrower characteristics. Amromin et al. (2018) find that IO borrowers are generally more financially sophisticated than the average household. This points towards the fact that IO borrowers have a higher ability to plan consumption due to a better understanding of financial products. Several papers, such as Piskorski and Tchistyi (2011), Cocco (2013), and Larsen et al. (2021) indeed show that the higher financial flexibility offered by IO mortgages help borrowers to better plan consumption over the life cycle. For young borrowers, access to IO mortgages allow them to smooth consumption over the life cycle by allowing them to postpone repayments to a future point when their income is higher. Access to IO mortgages allows older borrowers to relax otherwise binding liquidity constraints. Moreover, across all age groups, this access is beneficial for households that expect house prices to increase. Other research shows, however, that IO borrowers do not manage to plan consumption over the life cycle. Laibson (1997) finds that the increase in liquidity that mortgage products such as IO mortgages offer cause excessive leverage and consumption. Amromin et al. (2018) show that IO borrowers in the U.S. are more likely to default on their mortgage compared to similar households with traditional mortgages. Using a survey of U.K. mortgage holders, Gathergood and Weber (2017) find that individuals with present-biased preferences and poor financial literacy are more likely to take out an IO mortgage.

Another related area in the literature tries to explain why consumption is sensitive to an anticipated income reduction, i.e., why consumers fail to smooth consumption over the life cycle. Fuchs-Schuendeln and Hassan (2015), Ganong and Noel (2019), and Baugh, Ben-David, Park, and Parker (2021) indicate that the consumption response to expected income changes is consistent with behavioral consumer models with present-biased or myopic households. Andersen et al. (2020a) argue that lack of consumption smoothing is consistent with rational models, where households experience unanticipated borrowing constraints. Consistent with the idea of rational agents with

unanticipated borrowing constraints, we find that LTV matters in terms of refinancing tendencies. However, we do not rule out behavioral consumer models, as we are unable to test for differences in preferences due to lack of a good measure of preferences in the data.

The remainder of the paper is organized as follows. Section 2, in addition to describing the Danish mortgage system and the details concerning our dataset, presents summary statistics of the mortgage choice when the current IO period ends. Next, Section 3 examines consumption behavior around the end of an IO period and across various mortgage choices, as well as IO periods of various durations. Section 4, apart from analyzing consumption behavior at expiration of the IO period across borrower characteristics, studies debt and saving behavior around the expiration of the IO period to determine why the expiration of the period affects borrowers differently. Section 5 then discusses whether the amortization choice at expiration is voluntary or forced. Finally, Section 6 concludes.

2 Data

To examine the consumption behavior of IO borrowers, we apply panel data from 2003 to 2018 that combines mortgage data from all mortgage banks in Denmark from 2009 and register-based data on socioeconomic data, property data, and demographical data at the level of the individual for the whole period. Administrated by Statistic Denmark, the register-based data covers all tax-liable individuals in Denmark. As mortgage choices are typically made on household level, we use a family identifier to aggregate data to the household level.

2.1 Danish mortgage system

Before going into detail about our dataset, we briefly present the Danish mortgage system. In Denmark, mortgage banks provide mortgages, which are funded using covered bonds. The mortgage banks work as intermediaries between borrowers and investors. Borrowers take out mortgages, the mortgage bank then issues a series of covered bonds (backed by mortgage pools) to collateralize the payments of mortgage lenders. The covered bonds are listed on the Nasdaq Nordic exchange, where they are sold to investors.

Danish borrowers can borrow up to 80% of the property value. Like the U.S., traditional mortgages in Denmark have an annuity-style, 30-year fixed-rate mortgage (FRM) with a penalty-free option to prepay the mortgage. Since 1996, adjustable-rate mortgages (ARMs) have also been available to Danish borrower and are offered with various rate, reset frequencies from three months to 10 years. In late 2003, IO mortgages became available. A special feature of IO mortgages in Denmark is that the IO period, i.e., the non-amortizing period, is limited to 10 years.[1] Hence, after 10 years, the borrowers are forced to start amortization, if not, then they refinance their mortgage

[1]Since 2017, borrowers with an LTV below 60% have had access to IO mortgages with no repayments until maturity at 30 years. This new IO mortgage, introduced at the very end of our sample, is thus unlikely to affect our results.

to a new one. If an IO borrower wants to start amortization before the IO period expires, the procedure is easy and does not cost anything. An IO period can be shortened on a quarterly basis, requiring only a call to one's bank advisor.

The ARM and IO mortgage market is large. Figure 1a illustrates the share of ARMs and IO mortgages in Denmark from 2003 to 2019. The fraction of ARMs increases from 28% in 2003 to 68% in 2013, subsequently slowly falling to 52% in 2019. IO mortgages fast become popular after being introduced in 2003. In 2007, IO mortgages comprise 40% of mortgages in Denmark, the share increasing to 56% by 2013, after which it slowly begins deteriorating and only accounts for 44% of mortgages in 2019. From 2009 to 2013, the increasing use of ARMs and IO mortgages is driven by an increasing market for IO-ARMs and a decline in the market for repayment mortgages. From 2013 to 2019, the decline in both IO mortgages and ARMs is caused by a rising market for repayment FRMs.

In Figure 1b, we plot the average short- and long-term mortgage rate on Danish mortgage-backed bonds from 2003 to 2019. Typically, the interest rate on ARMs and FRMs follows the short- and long-term bond yields, respectively. From 2003 to 2008, yields are generally increasing; the short-term rate (long-term rate) from 2% (5.5%) in mid-2003 to 6% (7.5%) at the end of 2008. Since 2008, yields have fallen to around -0.5% for the short-term rate and 2% for the long-term rate. Especially the short-term rate has fallen dramatically. The rising gap between the short- and long-term rate increases the attractiveness of ARMs relative to FRMs, which likely explains the rising market for ARMs since 2009.

Besides the mortgage interest rate, borrowers also pay a contribution fee to compensate the mortgage bank for its administrative expenses and credit exposure.[2] The average contribution fee is around 0.5% until 2011, increasing since then to around 0.9% in 2016, after which it has been stable. Since 2011, the contribution fee has depended on the LTV, the mortgage type, and the mortgage interest rate type. More risky mortgages, such as IO mortgages, ARMs, and mortgages with a higher LTV are charged higher contribution fees. Across mortgages with an LTV of 80%, the contribution fee differs significantly by around 0.5 percentage points in 2016, a difference which has been increasing since 2011. Regarding LTV, the contribution fees are typically based on whether the borrower has an LTV below 40%, in between 40% and 60%, or above 60%. In 2014, the contribution fee is around 1.00% to 2.05% for borrowers with a mortgage between 60% and 80%, whereas it is around 0.75% to 1.35% for those with LTV between 40% and 60% and around 0.27% to 0.60% for those with an LTV below 40%.[3] The decline in IO mortgages and ARMs since 2013 is caused by the increase in contribution fees for these mortgages.

[Figure 1 about here.]

[2] If a borrower defaults on a mortgage, the mortgage banks pay out the corresponding bonds or replace the defaulted mortgages. Hence, mortgage banks bear the credit risk and must then be compensated.

[3] Statistics are based on The Danish Ministry of Industry, Business, and Financial Affairs (2016), Danish Competition and Consumer Authority (2020), and The Danish Ministry of Industry, Business, and Financial Affairs (2014).

Denmark does not have a creditworthiness system like the FICO score system in the U.S. To be granted any kind of mortgage in Denmark, borrowers must be able to afford a traditional FRM with a maturity of 30 years. This restriction ensures that the creditworthiness does not vary across borrowers with IO mortgages and repayment mortgages, and mortgages with an adjustable interest rate and fixed interest rate.

Danish borrowers face minimal barriers when refinancing mortgages. FRMs include a penalty-free prepayment option, which is also the case in U.S.; however, all Danish mortgages are also recourse mortgages. Thus, Danish borrowers have the option to prepay their mortgage by repurchasing bonds at face value (as in the U.S.) or at market value. The option of repurchasing bonds at market value is beneficial for borrowers in times with rising interest rates, whereas the face value is preferable when interest rates are falling. A second feature that eases refinancing for Danish borrowers is the fact that they are allowed to add refinancing costs to the mortgage principal, even in cases where doing so costs drives the LTV to exceed 80%. Additionally, for borrowers with mortgages with an LTV above 80%, refinancing the mortgage without cashing out is possible, if the purpose for doing so is to extend maturity and/or to reduce mortgage interest rates.

2.2 Details of our data set

Our analysis of IO borrowers centers around the end of the IO period. For each borrower, we define IO periods based on the start and end dates of IO periods that mortgage banks have registered. If an IO borrower has several mortgages, the IO period is based on the longest one. An expiring IO mortgage is defined as an IO mortgage with an IO period longer than 9.5 years, whereas shorter IO periods are defined by the length of the IO period in years.[4] Our dataset includes 116,422 households with IO mortgages originating between 2003 and 2008, i.e., we only include mortgages when we are able to track the IO mortgage when it expires.[5] Due to limited availability of mortgage data before 2009, we focus on IO borrowers who have their IO mortgage for at least six years.

The key variables in our analysis belong to three broad categories: mortgage-specific variables, household-specific variables, and consumption. Mortgage-specific variables of interest are ARM and LTV. ARM is a dummy variable that takes a value of 1 for an ARM and 0 for an FRM. LTV is the loan amount to the property value that the mortgage bank has registered.

Household-specific variables include age group, income, income growth, debt to assets, stock market participation, risky asset ratio, educational level, and regional dummy variables. *Age*

[4]The beginning and end of an IO period are typically fixed to quarters, so when defining the expiration of an IO period, we allow for smaller deviations (0.5 years) in the IO period. For IO borrowers that refinance or start amortization before the IO period expires, smaller deviations in the IO period are of no concern, as the IO periods are all used for the same reason - to reflect the mortgage choice and consumption behavior of IO borrowers in terms of early amortization or early refinancing.

[5]This results in IO periods ending between 2009 and 2018. To determine refinancing patterns, we must be able to follow the household for at least one year after the end of the IO period. Therefore, expirations in 2018 are excluded from the analysis.

groups reflects the average age of adults in the household, measured in the year the mortgage originates. We distinguish between three age groups: households below 39 years of age, between 40 and 54 years of age, and above 55 years of age. *Household income* is the disposable income of the household, i.e., total income less interest payments and tax payments. *Household income growth* is the annual average of the change in the logarithm of income over three years. *Debt to assets* is defined as the total debt over total assets, where total assets include bank, bond, and stock holdings, in addition to the public property value of all of the properties the household owns. *Stock market participation* takes a value of 1 for households that own stocks, and 0 otherwise. *Risky asset ratio* is the sum of stocks and mutual funds divided by the total sum of liquid assets, i.e., bank, bond, and stock holdings. We use three *educational levels*: primary school or less (level 1), secondary school or vocational education (level 2), and short- medium-, or long-term higher education, or PhD or similar (level 3). The educational level is based on the highest education in the household as reported by Statistic Denmark. Finally, we include *regional differences* by including the region where the property is located. The regions are based on the five administrative regions of Denmark: Copenhagen, Zealand, Southern Denmark, Central Jutland, and Northern Jutland.

Consumption is imputed from income and balance sheet characteristics, as done by Leth-Petersen (2010) and others.[6] The measure is based on the household's liquid budget constraint. More specifically, we define consumption as disposable income less net liquid savings, i.e., an increase in liquid assets less than the increase in mortgage debt, bank debt, or other debt. Liquid assets correspond to the bank deposits and the balance of private pension schemes. We exclude the market value of stock and bond holdings from liquid assets as it makes the consumption measure extensively volatile under extreme market conditions for the *few* households with significant positions in the stock and debt market.[7]

We disregard consumption for self-employed individuals, also in years when the household buys or/and sells real estate, as the imputed consumption is unreliable. For self-employed individuals, imputed consumption misrepresents actual consumption due to unstable income tax conditions and the fact that the value of their business is difficult to estimate (Browning and Leth-Petersen (2003)). In years when housing transactions occur, consumption is unreliable as it is based only on liquid assets. Hence, only the debt will be affected in the consumption measure when real estate is bought or sold. Further, we exclude households when mortgages are registered twice in refinancing years. When households refinance their mortgage, the mortgage that ends and the new mortgage are sometimes both registered in the refinancing year. This increases the borrowers' level of debt to an extreme level in the refinancing year. To ensure that extreme debt values caused by mortgages that are registered twice do not drive the consumption effects of refinancing, we exclude borrowers

[6] Browning and Leth-Petersen (2003), who compare data from a Danish Expenditure Survey to administrative data, find that the imputed consumption measure is a measure of good quality. Koijen, van Nieuwerburgh, and Vestman (2015) find that the imputed register-based consumption measure is preferable to self-reported consumption in survey data, based on findings of substantial reporting errors in Swedish consumption survey data.

[7] Baker, Kueng, Meyer, and Pagel (2021) show that the imputed consumption measure may misrepresent actual consumption in years where retail investors buy and sell assets. Only a small proportion of Danish households invest on their own, which is why we do not expect this to affect our results significantly.

with mortgages that are registered twice.

2.3 Mortgage choice when IO period ends

IO borrowers can end the IO period early (before it expires) to refinance to a new mortgage or to start amortization early. When the IO period expires, IO borrowers have a similar choice. They can follow the initial repayment plan of the IO mortgage and start amortization, or they can refinance to a new mortgage, if granted one. Whereas early amortization is optional, IO borrowers are committed to start amortization when the IO period expires, if no refinancing occurs. As described in Section 2.1, both the procedure for refinancing and the procedure for shortening the IO period are relatively easy and involve low costs up front. Additionally, the end of an IO period can also be a result of repaying mortgage debt or the fact that the household ceases to exist, e.g., borrowers divorce, start new relationships, or die.

In Figure 2, we split the sample into four different groups. The first three groups consist of households that end the current IO period after 6, 7, and 8 years, respectively. The fourth group comprises households that let the current IO period of 10 years expire. For each group, we then illustrate the frequency of the possible mortgage choice at the end of the IO periods.[8]

[Figure 2 about here.]

Figure 2 shows that 70.61% of all IO mortgages (102,657 out of 128,956 observations) in the sample are kept for less than 10 years. For around 50% of the IO mortgages refinancing ends the IO period early - most frequently as a new IO mortgage. On the other hand, very few IO borrowers (6%) start amortization early. For the remaining IO mortgages, half of the IO periods end early because borrowers divorce, start a new relationship, or die, whereas the other half ends the IO period early to repay the IO mortgage without setting up a new mortgage. For IO mortgages kept until the IO period expires, 61.72% of the IO borrowers start amortization, whereas only 19.02% refinance to a new mortgage. Around 14.95% of the IO mortgages end because borrowers divorce, start a new relationship, or die, and the remaining (4.31%) IO mortgages end because borrowers repay the IO mortgage.

Overall, most IO borrowers end the IO period before it expires. Typically, they do so by refinancing the mortgage to a new one (mostly a new IO mortgage). This tendency is unsurprising due to low refinancing costs and the favorable market conditions on the mortgage market, with declining interest rates in the refinancing period that the present study is investigating. When IO borrowers let the IO period expire, most of them start amortization. This indicates that refinancing during the IO period is common and that the choice of keeping the IO mortgage until expiration is a voluntary decision or due to borrowing constraints that force IO borrowers to start amortization. We will examine this in section 5.

[8]The mortgage choice reflects the mortgage choice during the year in which the IO period ends or in the year after. We account for the mortgage choice in the year after the end of the IO period, as IO borrowers that end the IO period at the end of the year may only be allowed to refinance the year after the end of the IO period.

Among others, age is found to be a fundamental driver in terms of how IO mortgages are used (Larsen et al. (2021)), as well as in terms of refinancing behavior (Andersen, Campbell, Meisner-Nielsen, and Ramadorai (2020b)). Thus, age differences are also expected regarding the mortgage choice. Older households with a home equity that is already high will have no or little incentive to start amortization, whereas the remaining age groups have a higher incentive to start amortization. Young households with relatively little home equity may start to build up home equity, whereas middle-aged households may have the incentive to reach a certain level of home equity before retirement. In general, borrowers across all age groups also have the incentive to lower LTV to minimize the contribution fee and, thus, the cost of debt.

To examine this further, we repeat Figure 2 across households within different age groups and show the result in Figure 3. The columns refer to various IO periods ranging from 6 to 10 years. The rows represent age groups (corresponding to the borrowers' age at the origination of the mortgage). Row one corresponds to households with an average age below 39; row two to the average age between 40 and 54, and row three to the average age above 55.

[Figure 3 about here.]

Figure 3 indeed supports the expected age differences in mortgage choices at the end of the IO period. The overall tendencies in Figure 2 remain unchanged, but older households almost never start amortization before the IO period expires. At expiration, a lower fraction of older households also tends to start amortization compared to the other age groups. Instead, older households tend to cease to exist or refinance to a new IO mortgage.

In general, existing literature also finds that many other variables besides age affect refinancing tendencies. Some examples are education, housing wealth, income, financial wealth, marital status, having children, and mortgage interest rate type. To investigate how other household and mortgage characteristics affect refinancing tendencies at the end of the IO period, we run probit estimations comparing the tendencies of IO borrowers to refinance after 6, 7, 8, and 10 years relative to starting amortization after 10 years. We also compare their tendencies to start amortization after 6, 7, or 8 years relative to starting amortization after 10 years. The probit estimation is specified as

$$\begin{aligned} P(D_i^{Mortgage\ Choice} = 1 | X_i^{IO\ period}, MS_{i,\tau}, HS_{i,\tau'}) \\ = \Phi(\alpha_0 + \beta_1 X_i^{IO\ period} + \zeta_1 MS_{i,\tau} + \zeta_2 HS_{i,\tau'} + \varepsilon_{i,t}), \end{aligned} \tag{1}$$

where the dependent variable is a dummy indicating whether the household (a) refinances to an IO mortgage, (b) refinances to a repayment mortgage, or (c) starts amortization early. We run the probit estimation separately for the duration of each IO period and each mortgage choice (a, b, and c), the dependent variable taking a value of 0 for IO borrowers that start amortization after 10 years for all of them. $X_i^{IO\ period}$ includes $avg(CTI)_i^{IOperiod}$, $Retirement_i^{IOperiod}$, and $Unemployment_i^{IOperiod}$; $avg(CTI)_i^{IOperiod}$ is the average consumption to lagged income during the IO period, $Retirement_i^{IOperiod}$ is a dummy indicating whether an individual in the household

retires during the IO period, and $Unemployment_i^{IOperiod}$ is an indicator for whether an individual in the household is unemployed at some point during the IO period. $HS_{i,\tau}$ refers to *Household specifics* and includes age groups, educational level, gender, singles vs. couples, number of adult residents, kids living at home (in IO period and/or after), income, income growth, bank holdings, stock market participation, and risky asset share. $MS_{i,\tau}$ refers to *Mortgage specifics* and includes mortgage interest type, as well as LTV and a dummy for whether LTV exceeds 80%. We also control for regional effects and origination year.

Mortgage and household characteristics are measured just prior to the base year, i.e., the year corresponding to the IO period where refinancing or early amortization happens. So, when estimating refinancing probabilities after seven years, our analysis is based on the seventh year of the IO period. Thus, the base year is used for both IO borrowers that refinance after seven years (non-keepers) and those that start amortization at expiration (keepers). We do so to ensure comparable characteristics over time between non-keepers and keepers. LTV and the mortgage interest type (ARM vs. FRM) are measured one year prior to the base year and household characteristics two years before. Φ is the standard normal cumulative distribution function.

[Table 1 about here.]

Table 1 reports the average partial effects of the probit estimation, for IO periods of 7 and 10 years. Columns 1 to 4 show that having an ARM and being unemployed during the IO period decreases the probability of refinancing. For IO borrowers that retire during the IO period and for those participating in the stock market, we find the opposite effect on the probability of refinancing. In particular, having an ARM has a large impact on refinancing tendencies, with effects ranging from 13.4% to 38.6%. Borrowers holding stocks are 2.6% to 4.6% more likely to refinance before the IO period expires relative to starting amortization at expiration. Solely regarding refinancing to an IO mortgage at expiration, we find that a risky asset share that is one percentage point higher significantly increases the probability of refinancing by 4.7%. Unemployment during the IO period decreases the probability of early refinancing by 2.1% to 4.8%, whereas borrowers that retire during the IO period are 2.9% to 5.5% more likely to refinance early or at expiration. These findings are consistent with former findings and expectations. Favorable interest rate movements on the mortgage market in the refinancing period (Figure 1b) give IO borrowers with FRMs an incentive to refinance to an ARM. The lower, unstable future income profile of unemployed borrowers decreases their ability to obtain a new IO mortgage and increases the advantage of keeping the IO mortgage until expiration. For IO borrowers that retire during the IO period, the ability to refinance to a new IO mortgage is typically good, since LTV is generally low at retirement. The refinancing incentive for retired households may be explained by older households moving to a smaller property or a more senior friendly house, by the changing economic situation around retirement (where a new type of mortgage may be optimal), or by older households refinancing to a new IO mortgage to ensure a long IO period after retirement.

Several factors affect the likelihood of refinancing to an IO mortgage and a repayment mortgage differently. Having an LTV above 80% only significantly affects the probability of refinancing to an IO mortgage, whereas LTV only slightly affects the likelihood of refinancing to a repayment mortgage. More specifically, we find that highly indebted IO borrowers with an LTV above 80% are 4.6% more likely to keep their mortgage until the IO period expires and start amortization rather than refinancing to a new IO mortgage after seven years (column 1). At expiration of the IO period, however, the effect is insignificant for borrowers that refinance to an IO mortgage (column 2). Columns 3 and 4 show that having an LTV that is one percentage point higher increases the likelihood of refinancing to a repayment mortgage by 0.1%, whereas we find no additional effect of having an LTV above 80%. The effect of LTV supports the fact that access to IO mortgages is limited for highly indebted IO borrowers (with an LTV above 80%), whereas this is not the case for access to repayment mortgages. Thus, the results indicate that highly indebted IO borrowers may be forced to keep their IO mortgage throughout the IO period and start amortization when the IO period expires. The consumption level during the IO period also affects the probability of refinancing to IO mortgages and refinancing to repayment mortgages differently. IO borrowers that consume more relative to income during the IO period are more likely to refinance to a new IO mortgage and less likely to refinance to a repayment mortgage during the IO period, which is in contrast to IO borrowers that start amortization at expiration. At expiration of the IO period, the consumption level during the IO period has no significant effect on refinancing behavior. Higher income growth decreases the probability of refinancing to a new IO mortgage after 7 or 10 years but increases the likelihood of refinancing to a repayment mortgage when the IO period expires. More specifically, we find that an expected annual income growth of 1% over three years decreases the probability of refinancing to an IO mortgage after seven years by 11.8% (column 1) and to an IO mortgage after 10 years by 7.7% (column 2), relative to starting amortization when the IO period expires. Contrarily, column 4 shows that IO borrowers with a 1% higher than expected annual income growth over three years are 14.0% more likely to refinance to a repayment mortgage rather than start amortization at expiration. The existing literature (Cocco (2013) and Larsen et al. (2021)) indicates that future income growth is a main driver for establishing IO mortgages; hence, our results indicate that IO borrowers indeed follow their initial repayment plan of the IO mortgage when experiencing income growth in the IO period.

Fundamental factors for early amortization are ARM and LTV (column 5). IO borrowers holding an ARM are 2.8% more likely to start amortization early than to start amortization when the IO period expires. LTV, on the other hand, slightly decreases the likelihood of early amortization. Comparing similar borrowers that only differ regarding LTV, we find that the probability of starting amortization early rather than starting amortization at expiration is 0.1% lower for a borrower with an LTV that is one percentage point higher.

Finally, we find that IO borrowers in Copenhagen are more likely to refinance and start amortization early compared to IO borrowers from other regions in Denmark. Thus, IO borrowers in

Copenhagen are the least likely to keep the IO mortgage until the IO period expires and start amortization. For robustness, we include probit estimations for all IO periods (6 to 10 years) in Tables IA.1, IA.2, and IA.3 in the Appendix. Overall, the results for the six and eight-year IO periods are similar to those for the seven-year IO period.

Overall, we show that refinancing behavior and early amortization are driven by debt, age, income profile, and stock market participation, but also differ according to region. Two key findings regarding the summary of mortgage choices at the end of IO periods are: (1) refinancing is common, and (2) IO borrowers that keep the IO mortgage period until the IO period expires (keepers) may face borrowing constraints, indicating that they might be unable to refinance to a new IO mortgage. If keepers reflect rational agents without borrowing constraints, they are indeed following their initial repayment schemes. Hence, they are not exposed to sudden shocks and changes in their lives during the IO period that affect their optimal choice about repayment schemes. If exposed to sudden shocks or fundamental changes in their economic or financial situation, a rational agent would refinance to adjust to the changes. Therefore, we expect that the consumption of keepers is indeed more likely to be unaffected when the IO period expires. However, as we find that having an LTV above 80% is a fundamental driver for the probability of IO borrowers refinancing to a new IO mortgage, we must consider the possibility that IO borrowers keep their mortgage because they are unable to refinance. If so, IO borrowers may fail to smooth consumption over the mortgage life cycle because they face borrowing constraints. To investigate this further, we will examine the underlying consumption behavior of the different mortgage choices around the end of the IO period in the following section.

3 Consumption effects around the end of the IO period

As predicted by the permanent income hypothesis, rational IO borrowers should be able to smooth consumption over the mortgage life cycle as the amortization period is planned, resulting in an expected reduction in disposable income. Therefore, we expect no consumption response at expiration for rational IO borrowers that follow the initial repayment plan and start amortization when the IO period expires. However, this is only the case for unconstrained IO borrowers. If the IO borrowers unexpectedly face borrowing constraints, we expect a negative consumption response to the increase in mortgage payments at expiration. Likewise, we expect that IO borrowers that voluntarily start amortization before the IO period expires do not change consumption when the amortization period starts. Borrowing constraints do not directly affect the decision to start amortization early; however, a negative consumption response among IO borrowers that start amortization early may also appear if IO borrowers start amortization early to commit themselves to limit consumption. When IO borrowers choose to refinance to a new IO mortgage, consumption is expected to increase or remain unchanged. However, the consumption response depends on the underlying reason for the refinancing. If the borrowers choose to refinance to prolong the IO period, everything else equal, consumption should be unaffected. If they refinance to obtain better

mortgage conditions (i.e., a mortgage rate decrease), consumption may increase as their disposable income increases. If they refinance to borrow more, consumption is expected to increase in the short run, but we do not expect consumption to change permanently. A higher principal will increase mortgage payments, which decreases consumption, everything else equal. However, during the IO period where only interest is paid, an increase in debt will only minorly affect the mortgage payments. Indeed, falling mortgage rates over the refinancing period in our sample will likely offset the increase in interest caused by an increase in the principal. Finally, we expect no change or a reduction in consumption for borrowers that refinance to a repayment mortgage. The underlying intuition is the same for borrowers that start amortization early. However, since IO borrowers that refinance benefit from falling mortgage rates (in our sample) and have the possibility to extend the maturity, we expect the consumption effect to be smaller for borrowers that refinance to a repayment mortgage compared to those that keep the IO mortgage throughout the IO period and start amortization. For IO borrowers that refinance at expiration of the IO period, we expect a larger reduction in consumption compared to those that refinance early. If a household faces borrowing constraints and is not granted for a new IO mortgage, the second best alternative is to let the IO period expire and refinance to a new repayment mortgage at expiration to lower mortgage payments as much as possible.

3.1 Identification

To investigate the consumption effect of ending the IO period across mortgage choices, we apply an event study, specified as:

$$\frac{Outcome_{i,t}}{Income_{i,t-1}} = \alpha_0 + \sum_{k=-4}^{3} \delta_k TTE_{i,t}^k + \zeta_1 C_{i,t-2} + \zeta_2 ARM_{i,t-1} + \psi_t + \varepsilon_{i,t}, \tag{2}$$

where *outcome* is the outcomes of interest, i.e., consumption, mortgage payments, annual change in mortgage debt, annual change in bank holdings, and annual change in bank debt, all measured relative to lagged income. Besides consumption, we also include debt outcomes and bank holdings to understand consumption patterns for the different mortgage choices. When measuring *time to end (TTE)*, *end* refers to the end of the IO period. A *TTE* equal to 0 refers to the year where the IO period ends and refinancing occurs or amortization begins, -1 refers to the year before, -2 to two years before, and so on. The event window includes four years before and three years after the IO period ends. The vector of controls, $C_{i,t-2}$, is measured at time t-2 and includes the number of adult residents, a dummy for kids living at home, and a dummy for gender, as well as dummy variables for educational levels, debt to asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and age-group dummies reflecting their age at origination of the IO mortgage. ψ_t includes year fixed effects to account for aggregate shocks. To obtain the effect of ending the IO period across mortgage choices and the various lengths of the IO period, we run the regression separately for each mortgage choice

and each length of IO period. Due to missing mortgage data before 2009, the six-year IO period only runs from -3.

3.2 Results

Figure 4 illustrates the average values of consumption and the consumption effect (TTE) of the four years before and three years after the IO period ends. Average values are represented by dashed lines and plotted in the sub-figures to the left, whereas estimated consumption effects are represented by dotted lines and shown to the right. Panel a includes IO borrowers that end the IO period by refinancing to a new IO mortgage. Panel b includes IO borrowers that refinance to a repayment mortgage, and panel c consists of IO borrowers that end the IO period and start amortization. For all panels, we separate our sample of IO borrowers into four groups based on the length of their IO period. The light gray lines with round markers are based on IO borrowers that refinance or start amortization after six years, the gray lines with diamond markers represent IO borrowers that refinance or start amortization after seven years, and so on. Similarly, Figures 5 and 6 present the average values and the effect (TTE) around the end of the IO period for other outcomes of interest: mortgage payments, mortgage debt, bank debt, and bank holdings. Figure 4 illustrates the average values and effects for each length of the IO period, while Figures 5 and 6 plot the average of the estimated effects of each of the IO periods. In Figures 5 and 6, the dark gray line with asterisks is based on IO borrowers that refinance to an IO mortgage; the gray line with squares represents IO borrowers that refinance to a repayment mortgage, and the light gray line with triangles stands for IO borrowers that keep the IO mortgage and start amortization. For robustness, we include average values and effects separately for each length of IO period in Figure IA.1-IA.4 in the Appendix. We find the same overall results across IO periods.

[Figure 4 about here.]

[Figure 5 about here.]

[Figure 6 about here.]

For the identifying assumption to hold for the event study, the treatment timing must be exogenous. Figures 4, 5, and 6 show that this is indeed the case for the outcome variables. All outcomes are generally unaffected before and after the IO period ends, when household and mortgage specifics and time fixed effects are controlled for. This illustrates that if the IO period did not end, the outcome variables are expected to be unaffected.[9]

Panel a in Figure 4 shows that the average IO borrower that chooses to refinance to a new IO mortgage after 6 to 8 years increases consumption after the refinancing.[10] For IO borrowers that

[9] We find a downward trend for consumption; however, it does not change the fact that consumption is generally unaffected before and after the expiration.

[10] The consumption effect happens partly in TTE = 0 and TTE = 1, depending on the time of year in which the IO period ends and whether the refinancing happens at TTE=0 or TTE=1.

refinance to an IO mortgage at expiration, the consumption is unchanged after the refinancing. For the average IO borrower that refinances to a repayment mortgage, consumption is unchanged (except in the refinancing year, TTE=1), both for early refinancing and refinancing at expiration (Figure 4, panel b). In the refinancing year (TTE=1), the consumption response is significantly different from 0, and it differs for IO borrowers that refinancing early and those that refinance when the IO period expires. The significant consumption response when refinancing reflects debt changes in the refinancing, and the difference in consumption responses reflects differences in debt choices when refinancing. We will comment on this later. For IO borrowers that start amortization early or at expiration of the IO period, the consumption pattern is cleaner as it involves no refinancing. Panel c in Figure 4 shows that consumption is reduced across all lengths of IO periods when amortization begins.

To understand the consumption behavior of IO borrowers that refinance, understanding the underlying purpose of the refinancing is crucial, i.e., whether the refinancing is used to, e.g., borrow more, restructure debt, or to benefit from falling mortgage rates. Figure 5 documents that mortgage payments increase when IO borrowers start amortization, i.e., when they start amortization or refinance to a repayment mortgage. This is expected. Due to falling mortgage interest rates during the period of interest and a possibility to extend the maturity (the repayment period), the increase in mortgage payments is lower for the IO borrowers that refinance to a repayment mortgage compared to those that start amortization. Consistent with our expectations, mortgage payments decrease slightly after refinancing for IO borrowers that refinance to a new IO mortgage.

Figure 5 also illustrates that IO borrowers that refinance take up more mortgage debt, especially those that refinance to an IO mortgage. IO borrowers increase mortgage debt by about 20% (5%) more of lagged income when refinancing to an IO mortgage (repayment mortgage) one year after the IO period ends compared to the year before. Some of the additional mortgage debt is, however, used to restructure debt, as the refinancing is also used to repay bank debt (Figure 6). As expected for IO borrowers that keep the IO mortgage and start amortization, we find no immediate response to debt when amortization starts.

A couple of additional results are also worthwhile mentioning. First, Figures IA.2 and IA.3 in the Appendix show that IO borrowers that refinance before the IO period expires take on more mortgage debt, whereas those that refinance at expiration repay a large amount of bank debt when refinancing. This indicates that IO borrowers refinance to a new IO mortgage before expiration to borrow more, whereas restructuring of debt is in focus for IO borrowers that refinance at expiration. This also explains why consumption differs in the refinancing year (TTE=1) for borrowers that refinance early and for those that refinance when the IO period expires. Second, the debt changes are generally smaller for those that refinance to a repayment mortgage compared to those that refinance to an IO mortgage. This explains the lower response in consumption for borrowers that refinance to a repayment mortgage compared to those that refinance to an IO mortgage. Despite

the fact that IO borrowers take on more debt when refinancing, falling mortgage interest rates during the period of interest reduce mortgage payments after refinancing. For both IO borrowers that refinance and those that start amortization, bank holdings are relatively unaffected by ending the IO period (Figure 6).

Overall, we show that the average IO borrower that refinance to a repayment mortgage does not change consumption persistently after refinancing and they only take on a bit more debt in the refinancing year. These borrowers thus succeed in starting amortization without cutting consumption persistently, indicating that these IO borrowers are better off when refinancing. On the other hand, consumption and savings decisions among the average IO borrower that refinances to a new IO mortgage are worrying. When refinancing to a new IO mortgage, household consumption increases or remains unchanged after refinancing and household debt increases significantly in the refinancing year. Results imply that IO borrowers that rollover their IO mortgage to a new one seem to benefit from refinancing in the short run, but this may not be the case in the long run, as these future IO borrowers are more indebted and hence, more likely to end in financial difficulties, everything else equal. How the future amortization period will affect these IO borrowers depends on, for example, house price changes and on how saved repayments are used during the IO period. Since only time will tell, examining the data when it is available to see what happens is worthwhile.

For IO borrowers that keep the IO mortgage throughout the IO period and start amortization, all of them experience a fall in consumption, on average. This is consistent with findings in the existing literature. With data and a setting almost similar to ours, Andersen et al. (2020a) document an increase in mortgage payments of 9% and a consumption reduction of 3% in response to the expiration of the IO period, for the average IO borrower. Similarly for our sample, we find that mortgage payments increased by 8.2% and consumption decreased by 3.5% of income, on average, when the IO period expires (Table IA.4 in Appendix). The results in Table IA.4 are based on the event study, specified in equation (2), using a dummy indicating the before and after period (*Expired*), instead of TTE.[11] When amortization begins for early amortization, we document average increases in the mortgage payments between 5.6% and 6.2%, and average reductions in consumption between 1.6% and 3.7% of income.

For the relatively few IO borrowers that start amortization early, the consumption reduction may be seen as a commitment to limit consumption; however, this is not a major concern, as the amortization choice is voluntary. But the fact that IO borrowers reduce consumption in response to an anticipated reduction in disposable income when the IO period expires may be worrying, as this reduction may imply a lack of consumption planning over the mortgage life cycle among IO borrowers. Does the consumption behavior of the average IO borrower reflect the consumption behavior of IO borrowers in general, or does it vary across borrower characteristics? Is the consumption reduction at expiration of the IO period voluntary or forced by borrowing

[11] We only estimate average consumption effects for IO borrowers that start amortization, as the consumption measure is clearly affected around a refinance and would thus bias an estimation of the average effect around refinances.

constraints? Among many other questions, answering them is essential for understanding what drives the lack of consumption smoothing over the life cycle of the mortgage. This is important for regulatory purposes. Do we need to extend regulations on the usage of IO mortgages to ensure financial stability and to prevent IO borrowers from being hurt financially when the IO period ends? If regulations need to be tightened, what type of IO borrowers should they apply to? In the next two sections, we will address these questions.

4 Consumption effects at expiration across borrower characteristics

Borrowers are motivated to use IO mortgages for many reasons. Age, income profile, liquidity constraints, debt level, house price expectations, and preferences are some characteristics of IO borrowers found to be fundamental to how the financial flexibility that IO mortgages offer is used in saving and consumption decision making over the life cycle of the mortgage. Therefore, differences across IO borrower types are also expected for the consumption response to the anticipated change in disposable income at the expiration of the IO period.

As a borrower characteristic that potentially affects the consumption behavior at the expiration of the IO period, we also include *how* IO borrowers use the extra liquidity in the IO period. If the IO period is used to save more in non-housing assets or to repay debt with higher costs, the household is likely to be better off in the future due to increased portfolio diversity or reductions in cost of debt. If IO borrowers instead are households with high consumption that use saved repayments to raise consumption during the IO period, there is a general concern about higher default probabilities or undesirably low consumption in the future. One may argue that the saving and consumption choices during the IO period drive the consumption response when the IO period expires. Whereas there is a close link between present and expected future consumption in the long run, this is not necessarily the case in the short run, which is what we are examining here. In the long run, borrowers that consume more relative to income in the present will have to cut consumption in the future to repay debt. However, the future reduction in consumption does not have to occur at the expiration of the IO period. Even if a borrower chooses to consume a high fraction of income during the IO period, the borrower may potentially maintain consumption in the amortization period by initiating new debt, selling stocks and bonds, withdrawing funds from their bank holdings, or income growth. Thus, a higher consumption level during the IO period does not inherently drive a reduction in consumption at the expiration of the IO period. In the following analysis, we use the average CTI in the IO period to reflect the saving and consumption level of IO borrowers during the IO period.

To study consumption behavior around the expiration of the IO period across different borrower characteristics, we rerun the event study, specified in Equation (2). As the event study now is centered around the expiration of the IO period, TTE instead refers to time to expiration. A TTE equal to 0 refers to the year where the IO period expires and amortisation starts, -1 refers to the year before, -2 to two years before, and so on. To account for differences in consumption

responses across borrower characteristics, we include dummy variables for the specific characteristic of interest, included separately and interacted with *TTE*. For simplicity, we run the event study separately for one (or two) borrower characteristic(s) at the time. We cover the following borrower characteristics: age groups, regions, quartiles of average CTI during the IO period, whether kids live at home before and after expiration (the effect of kids moving from home), whether the borrower faces borrowing constraints (have a LTV above 80% one year prior to the expiration), income growth, and whether a borrower retires during the IO period.[12] Quartiles of average CTI during the IO period are measured annually relative to the mortgage origination year. To measure the effect of kids moving from home, we construct three groups differentiating between whether kids live at home during the IO period and three years after: (1) no kids living at home during and after IO period, (2) kids living at home during the IO period and no kids after the IO period, and (3) kids living at home during and after the IO period.[13] We run the event study on consumption and mortgage payments to investigate the consumption behavior and the exposure of IO borrowers to the expiration of the IO period.

Figures 7 and 8 plot the average values and the estimated effects of time to expiration for consumption from four years before the expiration to three years after, across age groups and across quartiles of average CTI during the IO period, respectively. Average values are represented by dashed lines and plotted in the sub-figures to the left, whereas estimated consumption effects are represented by dotted lines and shown to the right. Figure 9 illustrates the same statistics for the mortgage payments across age groups in panel a, and across quartiles of average CTI during the IO period in panel b. As for the average IO borrower, Figures 7, 8, and 9 verify that the exogeneity of the treatment timing is also fulfilled across age groups and across quartiles of average CTI during the IO period.

[Figure 7 about here.]

[Figure 8 about here.]

[Figure 9 about here.]

Figures 7, 8, and 9 show that age groups and the consumption level during the IO period are key determinants of the consumption response at expiration. This occurs despite the fact that all IO borrowers experience a significant increase in mortgage payments just after the expiration of the IO period, both across age groups and the consumption level during the IO period. More specifically, we show that the negative consumption response tends to increase with age. Older borrowers (above 55 years of age at origination of the IO mortgage) are most affected by the expiration, and young borrowers (below 39 years of age at origination) the least affected. IO borrowers with a

[12] Differences in preferences are not included in the analysis as we do not have a good measure of preferences.

[13] We exclude households where no kids live at home during the IO period and where kids live at home after the IO period due to very few observations.

higher CTI during the IO period reduce consumption more compared to IO borrowers with lower levels of CTI during the IO period.

For the event study across regions, kids living at home, borrowing constraints (LTV above 80%), income growth, and retirement, we find no variation in the consumption behavior around the expiration of the IO period. The results are included in Figures IA.5 to IA.9 in the Appendix.[14]

To investigate the average effect on consumption and mortgage payments before and after the IO period expires, we rerun the event study using a dummy indicating the before and after period (*Expired*), instead of *TTE*. To obtain the average effect of expiration across age groups and across quartiles of average CTI during the IO period, we run the regression separately for each age group and each quartile of CTI. Tables 2 and 3 present the results.

[Table 2 about here.]

[Table 3 about here.]

Table 2 documents a significant increase in mortgage payments between 7.7% and 9.3% relative to lagged income, on average, when the IO period expires. The average effect increases with age. After the IO period expires, average consumption to lagged income is reduced by 2.8% for borrowers below 39 years of age, 5.5% for borrowers between 40 and 54 years, and 5.9% for borrowers above 55 years of age. Across quartiles of CTI during the IO period, Table 3 shows that the average mortgage payment significantly increases when the IO period expires. Relative to lagged income, the average mortgage payment increases by 10.6% after the IO period expires for IO borrowers with the highest CTI, whereas it increases by 8.5%, 7.2%, and 7.2% of income for the other IO borrowers within quartiles 3, 2, and 1, respectively. For consumption, we find that the average IO borrower with the highest CTI (quartile 4) consumes 17.1% less of their lagged income after the IO period expires. For the average IO borrower within the third quartile of CTI, the consumption reduction is 9.2% of income. For the second lowest level of CTI (quartile 2), borrowers only reduce average consumption by 2.9% of income after expiration, whereas borrowers with the lowest level of CTI (quartile 1) increase consumption by 13.5% of income after the IO period expires.

As just pointed out, the response in terms of mortgage payments differs across quartiles of CTI and across age groups, a result likely to be caused by income level and leverage differences across borrower characteristics. Additionally, mortgage payments are also affected by interest rate movements. Within our event window ranging from 2009 to 2018, mortgage rates have fallen, which decreases mortgage payments for ARMs. To isolate the effect of the change in mortgage payments on consumption when the IO period expires, we estimate the elasticity of the response of

[14] In Figure IA.6, we find the consumption response at expiration of the IO period to vary across the groups, differentiating between kids living at home during and after the IO period. This effect is caused by age differences. In Figure IA.7, we find that the average older borrower with an LTV above 80% reduces consumption at expiration a bit more than the average older borrower with an LTV below 80%. The difference in the consumption effect is driven by a larger increase in mortgage payments at expiration for borrowers with a higher LTV and no borrowing constraints. The consumption response is indifferent across borrowers relative to the change in mortgage payments at expiration.

consumption to mortgage payments. We use a two-stage least squares (2SLS) regression analysis for this purpose, which is specified as:

First stage:

$$\frac{Mortgage\ payment_{i,t}}{Income_{i,t-1}} = \alpha_0 + \delta Expired_{i,t} + \zeta_1 C_{i,t-2} + \zeta_2 ARM_{i,t-1} + \psi_t + \varepsilon_{i,t} \tag{3}$$

Second stage:

$$\frac{Consumption_{i,t}}{Income_{i,t-1}} = \alpha_0 + \beta \frac{\widehat{Mortgage\ payment_{i,t}}}{Income_{i,t-1}} + \zeta_1 C_{i,t-2} + \zeta_2 ARM_{i,t-1} + \psi_t + \varepsilon_{i,t}, \tag{4}$$

where we instrument the change in mortgage payments using the expiration of the IO period (first stage) and then estimate its consumption effect (second stage). Thus, the first stage is similar to the estimation presented in Tables 2 and 3. Again, we run the regression across quartiles of CTI and across age groups. We include the same control variables as in Eq. (2).

[Table 4 about here.]

[Table 5 about here.]

Tables 4 and 5 present the coefficients and standard errors from the 2SLS estimations. Results show that for the average borrower below 39 years of age, the MPC out the increase in mortgage payments is 36.2%. Thus, experiencing an average increase in mortgage payments worth 7.7% of lagged income, young borrowers reduce consumption by 2.5% of lagged income when amortization begins. For the average borrower between 40 and 54 years of age (above 55), the MPC is 69.0% (63.1%), implying that with mortgage payments increases of 8.0% (9.3%) at expiration of the IO period, middle-aged (older) borrowers cut consumption by 5.5% (5.9%). Regarding consumption and savings decisions during the IO period, we find an MPC of 161.2% for the average IO borrower with the highest average CTI during the IO period (quartile 4), 108.4% for the second highest level (quartile 3), 40.2% for the second lowest level (quartile 2), and -186.6% for the IO borrowers with the lowest average CTI during the IO period (quartile 1). Thus, it corresponds to IO borrowers within quartiles 2, 3, and 4 cutting average consumption by 2.9%, 9.2%, and 17.1%, respectively, when the IO period expires. For IO borrowers in quartile 1, it corresponds to an increase in average consumption of 13.4% when amortization starts.

Overall, results are almost identical to findings in Figures 7 and 8, all of which supports the fact that age and the average CTI during the IO period are key determinants for the consumption response at the expiration of the IO period. The average consumption effect of the amortization period is equal for middle-aged and older IO borrowers but, as shown in Figure 7, the immediate consumption response to the expiration of the IO period is largest for older IO borrowers.

Testing multiple borrower characteristics that possibly affect the consumption behavior at the expiration of the IO period, we find the main drivers of the consumption response to the decrease

in disposable income at expiration are age and saving and consumption decisions made during the IO period. The results indicate that age and *how* IO borrowers use the financial flexibility offered by IO mortgages matters in terms of their tendency to smooth consumption over the mortgage life cycle. As saving and consumption decisions are likely to vary across age, differences in consumption responses at the expiration of the IO period across age groups may be explained by the fact that borrowers within age groups use saved repayments during the IO period differently. Therefore, to understand why the expiration of the IO period affects borrowers differently, we will examine debt and saving decisions across age groups and quartiles of CTI during the IO period.

4.1 Debt and saving decisions around IO expiration

To investigate debt and saving behavior around the expiration of the IO period, we repeat the event study for annual changes in bank debt and bank holdings. The results are presented across age groups in Figure 10 and across quartiles of average CTI during the IO period in Figure 11. The figures are set up similar to Figure 9, described in the previous section. Average effects of the amortization period across age groups and across quartiles of average CTI during the IO period are included in Tables 6 and 7, respectively.

[Figure 10 about here.]

[Figure 11 about here.]

[Table 6 about here.]

[Table 7 about here.]

Figure 10 shows that the average young IO borrower tends to repay bank debt during the IO period but stops doing so in the amortization period. On average, the change in bank debt for young borrowers is 2.3% lower during the IO period relative to after, whereas it is unchanged for the other age groups (Table 6). For the average older borrower, bank holdings are stable during the IO period, but during the amortization period they withdraw funds from their bank account. On average, the change in bank holdings is reduced by 4.8% after the IO period expires (Table 6). For the other age groups, bank holdings are relatively more stable around the expiration of the IO period. In contrast to older IO borrowers, the other groups tend to increase bank holdings both in the IO and amortization periods, though at a lower level (a reduction between 2.0% to 2.5%) in the amortization period.

Figure 11 illustrates that a low level of average CTI during the IO period (below median) reflects a tendency among IO borrowers to use saved repayments to repay bank debt or to put savings in their bank account during the IO period. When amortization starts, the borrowers in quartiles 1 and 2 reduce bank debt repayments relative to lagged income, whereas for households with high consumption during the IO period, the repayment plan is unchanged (quartile 3) around

the expiration of the IO period. The average borrower within the fourth quartile of average consumption during the IO period, in contrast, tends to build up more bank debt during the IO period and starts repayment after amortization begins. On average, bank debt repayments are 2.8% and 2.5% higher in the IO period relative to after expiration, for quartiles 1 and 2, respectively. For quartile 3, the effect on the change in bank debt is insignificant, on average. For quartile 4, the average change in bank debt is 1.5% lower after the IO period expires relative to before (Table 7). Regarding bank holdings, the average borrower that consumes the least during the IO period (quartile 1) uses the IO period to not only repay bank debt but also tends to put saving in their bank account during the IO period. When amortization begins, they stop doing so. For the second and third quartile of average consumption during the IO period, the borrowers save almost the same fraction of their income in bank holdings before and after the IO period expires. The borrowers that consume the most during the IO period (quartile 4) build up not only more bank debt during the IO period, but they also tend to withdraw funds from the bank account. In the following amortization period, they start to save in bank holdings. On average, IO borrowers in quartiles 1 and 2 save 12.3% and 1.6% more of their income in their bank account in the IO period compared to in the amortization period, respectively. For individuals with high consumption during the IO period (quartiles 3 and 4) savings in their bank account during the IO period and in the amortization period is not significantly different (Table 7).

Overall, the results indicate that young borrowers tend to take out an IO mortgage to repay more expensive bank debt during the IO period. For older borrowers, results indicate that IO borrowers use saved repayment to fund consumption in the IO period, i.e., IO mortgages are used as an alternative funding source to avoid withdrawing fund from bank holdings.

To account for potential variation in saving and consumption tendencies during the IO period within each age group, we also include an event study differentiating between both age groups and quartiles of CTI during the IO period. Figures 12 and 13 plot the effects of time to expiration.[15]

[Figure 12 about here.]

[Figure 13 about here.]

Figures 12 and 13 find no significant variations in saving and consumption decisions for young and middle-aged borrowers. However, among older IO borrowers, we find significant variation in the change in the bank account across quartiles of CTI during the IO period. Whereas older borrowers within the first quartile tend to save a great deal in the bank account during the IO period and withdraw funds from it after the IO period, older borrowers within the fourth quartile tend to do the exact opposite. For the older borrowers within the second and third quartiles, we find almost no change in the bank holdings around the expiration of the IO period. This pattern

[15] For robustness, effect of time to expiration on consumption in Figures IA.10 and IA.11 is shown in the Appendix. The results on consumption support previous results, showing that the negative consumption response increases as one ages and the consumption level during the IO period.

reveals that not all older IO borrowers use the saved repayments on consumption during the IO period. Indeed, some older IO borrowers tend to use saved repayments in the IO period to increase savings in the bank account.

In Section 4, we document that consumption behavior at the expiration of the IO period is driven by age and average consumption levels during the IO period. For young borrowers and for other borrowers that tend to save a high fraction of their income during the IO period, we find that average consumption is less affected, or even increases when the IO period expires. In this section, we find that the average young IO borrower tends to use saved repayments in the IO period to repay bank debt. This thus implies why they are less affected (regarding consumption) by the expiration of the IO period. When amortization on the mortgage starts, the increase in mortgage payments is offset by the fall in bank debt payments. Older borrowers within the first quartile of CTI during the IO period tend to use saved repayments in the IO period to save more in their bank account. These older IO borrowers manage to maintain consumption at the same level (or even increase consumption) in the amortization period by withdrawing funds from their bank account. For the middle-aged households, the results are mixed. Those within the first quartile of CTI during the IO period use the IO period to repay mortgage debt and increase bank holdings, whereas older borrowers withdraw funds from the bank account in the amortization period and middle-aged borrowers continue to increase bank holdings, though at a lower level in the amortization period. Borrowers that consume a high fraction of their income during the IO period reduce consumption relatively more in response to the anticipated decrease in disposable income when amortization starts. Generally, this is the true across all age groups, but it is most severe for older and middle-aged borrowers (Figures IA.10 and IA.11 in the Appendix). We find that for individuals with high consumption during the IO period, saved repayments during the IO period serve no other purpose than to increase consumption. Thus, this implies why expiration of the IO period affects them most.

5 Voluntary or forced choice to start amortization

To understand what drives the variation in the consumption response to the increase in mortgage payments when the IO period expires, we cannot ignore that the decision to start amortization may be either voluntary or forced. Figure 3 shows that IO borrowers are more likely to start amortization when the IO period expires relative to before expiration of the IO period, where it is more common to refinance the mortgage. This indicates that IO borrowers are either forced to start amortization because they are unable to obtain a new IO mortgage, or that the borrowers voluntarily choose to start amortization. Among all age groups, borrowers with low home equity have an incentive to start amortization at expiration of the IO period to lower the cost of debt and to ensure future flexibility in their mortgage choice. Specifically, the contribution fee depends on LTV and, thus, by decreasing LTV, the borrowers may lower their cost of debt. Regarding flexibility in future mortgage choices, a lower LTV increases the probability of being granted a new mortgage

in the future.

Findings in Section 2.3 suggest that IO borrowers are less likely to refinance to a new IO mortgage in the IO period if they have an LTV above 80%, indicating that IO borrowers may face borrowing constraints and are, hence, forced to start amortization when the IO period expires. We also find that borrowers using a lower fraction of saved repayments on consumption are more likely to refinance to an IO mortgage. Further, in Section 4, we document that young households generally smooth consumption over the mortgage life cycle. We argue that they are less affected by the expiration of the IO period because they use saved repayments to repay bank debt, hence offsetting the increase in mortgage payments at expiration with the reduction in bank debt payments. Thus, it is more likely that young IO borrowers start amortization voluntarily. This is not the case for the average IO borrower in the other age groups. Older IO borrowers mainly use IO mortgages as an alternative funding device for consumption, and middle-aged borrowers tend to be driven by a mixture of the two, though on a lower scale. This results in a more severe reduction in consumption when the IO period expires for middle-aged and older borrowers, on average.

[Figure 14 about here.]

Figure 14 plots the distribution of LTV one year prior to the expiration of the IO period. LTV is essential not only for the ability of borrowers to refinance but also for contribution fees. LTV clearly matters regarding refinancing tendencies. Except for the young borrowers, who all tend to borrow at the maximum of 80%, a lower fraction of borrowers that refinance to a new IO mortgage have an LTV above 80% just prior to expiration of the IO period compared to those that refinance to a repayment mortgage or start amortization at expiration. The LTV of middle-aged borrowers that choose to refinance to a new IO mortgage hover around 60%, whereas this is expectedly slightly lower (around 40%) for older borrowers. For the borrowers that refinance to a repayment mortgage or start amortization, LTV hovers around 70%-80% for the middle-aged borrowers, increasing in the level of consumption during the IO period, and 70% for the older borrowers. Hence, the results imply that middle-aged and older borrowers may be forced to start amortization when the IO period expires since they are unable to take out a new IO mortgage. This also supports the findings in Andersen et al. (2020a), who show that the average borrower cuts consumption in the amortization period as a consequence of not being granted a new IO mortgage at expiration, when they had otherwise expected to do so. However, the results do not rule out the possibility that the borrowers voluntarily choose to start amortization at expiration. The LTV of middle-aged and older borrowers that refinance to a new IO mortgage is centered around the two cutoff points (40% and 60%), of which contribution fees are lowered for the mortgage. This indicates that IO borrowers tend to refinance to a new IO mortgage if they have reached one of the two cutoff points. This suggest that IO borrowers voluntarily choose to start amortization when the IO period expires to reach a certain limit of LTV to lower contribution fees.

Overall, findings indicate that young IO borrowers voluntarily choose to start amortization at expiration. For middle-aged and older borrowers, the choice between starting amortization or

refinancing to a new IO mortgage seems to be driven by both borrowing constraints and a wish to increase home equity with the purpose of lowering the contribution fee to reduce the cost of debt.

6 Summary and conclusion

The existing literature documented that (1) IO mortgages are used sophisticatedly to better smooth consumption over the life cycle, and (2) IO borrowers do not manage to optimally plan consumption over the life cycle. By studying consumption behavior around the end of IO periods, we make one main contribution to the existing literature on IO mortgages: we document cross-sectional variation in consumption behavior around the expiration of the IO period across the age of borrowers and their level of consumption during the IO period. This suggests that borrower characteristics are fundamental to whether the IO borrower manages to smooth consumption over the life of the mortgage. In response to an anticipated increase in mortgage payments when amortization starts, young borrowers (below 39 years of age measured at origination) reduce average consumption significantly less than middle-aged (40-54 years of age) and older households (above 55). Across all age groups, the consumption response at expiration increases with the level of consumption during the IO period. Thus, IO borrowers that use saved repayments on consumption rather than savings during the IO period are hurt more regarding consumption when the amortization period begins. The variation in consumption response at expiration across age is in fact driven by *how* the age groups use the saved repayments during the IO period. The average young borrower uses the saved repayments to repay bank debt, whereas older borrowers use them for consumption. How middle-aged borrowers use saved repayments tends to be driven by a mixture of the two, but on a lower scale.

Our results are essential for regulatory purposes because IO mortgages are granted on the assumption that IO borrowers will smooth consumption over the life cycle of the mortgage. Young borrowers that want to use the IO period to repay bank debt are not significantly affected regarding consumption when the IO period expires. Hence, they manage to smooth consumption while minimizing debt costs. Additionally, we also find indications that these young borrowers voluntarily start amortization at expiration of the IO period. For young IO borrowers that tend to consume a high fraction of the saved repayments, the opposite is the case, which raises concerns about whether they manage to plan consumption optimally in the long run. Overall, findings suggest that granting IO mortgages to young borrowers should optimally depend on whether the young borrowers use the saved repayments on repaying bank debt or not. For middle-aged and older households with high home equity, no additional regulations are needed as high home equity allows the borrower to refinance to a new IO mortgage when the IO period expires. If the borrower chooses to start amortization at expiration, the choice must then generally be voluntary and a reduction in consumption an active choice. On the other hand, if middle-aged and older households have low home equity, the borrowers may face borrowing constraints and potentially be forced to start amortization at expiration. This suggests that regulations are needed to restrict the

use of IO mortgages for highly indebted borrowers. However, softer regulations may also be sufficient. Our results suggest that a reduction in consumption at expiration is avoided if borrowers use saved repayment to increase bank holdings in the IO period. Thus, to ensure consumption smoothing over the mortgage life cycle, it may be sufficient to require that banks help and advise borrowers to commit to increasing their bank holdings or other liquid holdings during the IO period. Furthermore, if the consumption response is caused by an unexpected borrowing constraint, as our results imply, advising IO borrowers better will likely limit the lack of consumption smoothing over the mortgage life cycle. Additionally, our results point to the fact that the granting IO mortgages should not only account for how saved repayments are used in the future IO period, but also for whether saved repayments are used on saving or consumption in the past IO period.

Refinancing during the IO period is common in Denmark. Thus, many IO borrowers rollover to a new IO mortgage during the IO period. We document that IO borrowers that refinance to a repayment mortgage consume the same before and after refinancing, and they only take on a bit more debt in the refinancing year. Results suggest that these borrowers succeed in starting amortization without cutting consumption, indicating that they are better off after refinancing. For IO borrowers that refinance to a new IO mortgage, we document an increase in consumption after refinancing. Thus, in the short run, they are better off after refinancing. However, in the long run, this is not necessarily the case. For the average IO borrower, refinancing to a new IO mortgage involves an increase in mortgage debt. All else equal, borrowing constraints will be stronger in the future for IO borrowers that rollover their IO mortgage to a new one, which will likely increase the negative consumption response when the IO period expires. However, the consumption response at expiration for the second IO mortgage will depend on, for instance, how IO borrowers use saved repayments during their second IO period and how house prices change. Unfortunately, the data does not allow us to follow rollovers to the expiration of the second IO period. Our findings suggests that future work on the consumption impact of IO mortgage rollovers is important and relevant.

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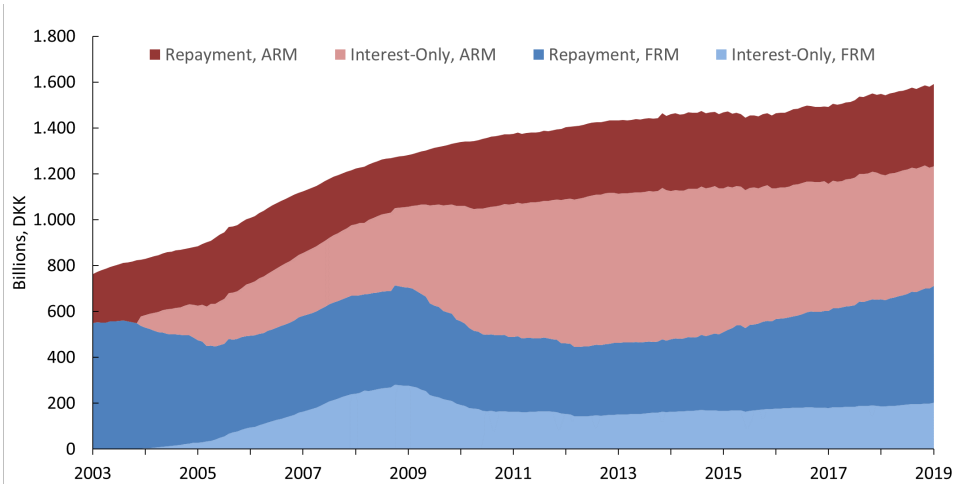
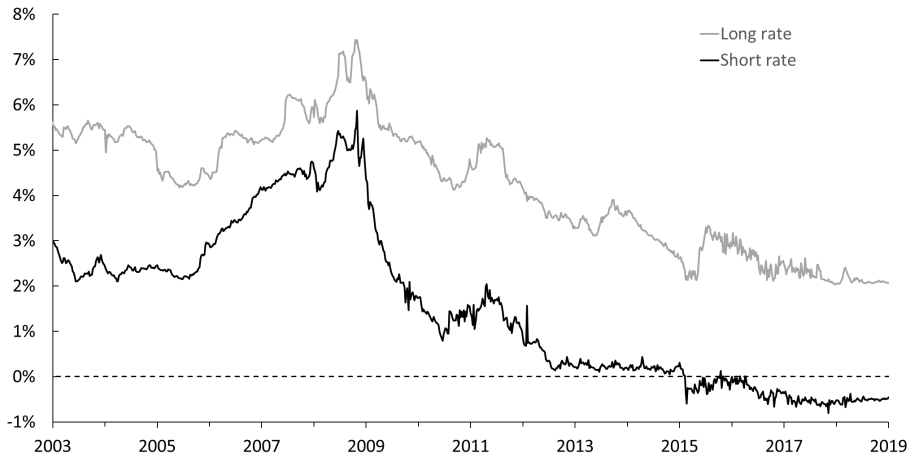


(a) Outstanding mortgages by type



(b) Average Danish mortgage rates

Figure 1: The Danish mortgage market. Panel (a) shows the face value of outstanding residential mortgages in Denmark in the period 2003–2019, on monthly basis. The total issuance is divided into four subgroups: interest-only FRMs (light blue area), repayment FRMs (dark blue), interest-only ARMs (light red), and repayment ARMs (darker red). Panel (b) presents the weekly average Danish mortgage rate, measured as the average yield-to-maturity on mortgage-backed bonds denominated in Danish Kroner. Data source: (a) Danmarks Nationalbank (b) Finance Denmark, from 2003 to 2019.

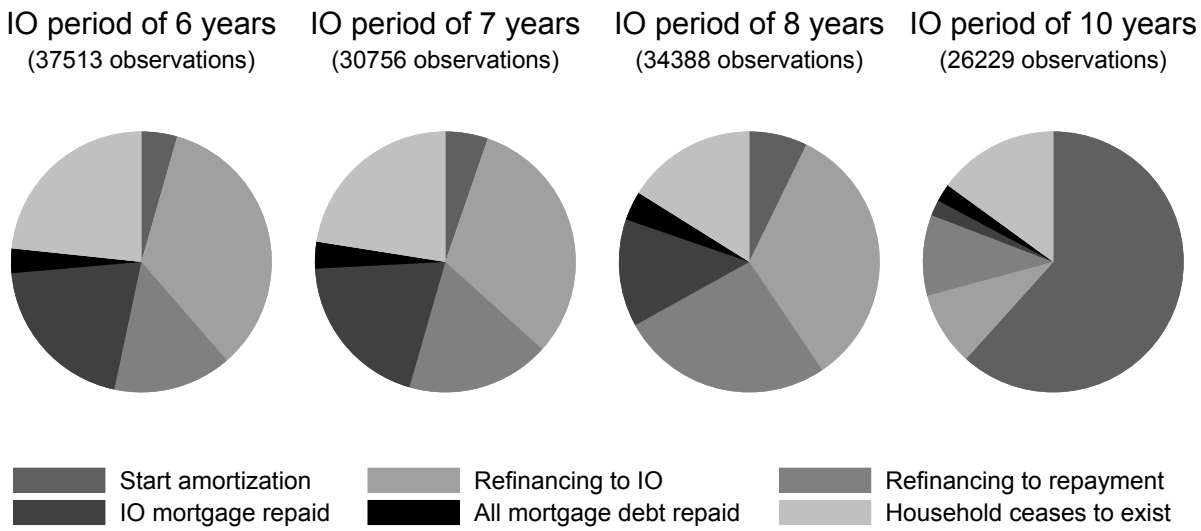


Figure 2: Mortgage choice. The figure presents interest-only (IO) borrowers' mortgage choice after IO periods of 6, 7, 8, and 10 years. The end of the IO period can be a result of the mortgage choices; starting amortization, refinancing to a new IO mortgage, refinancing to a repayment mortgage, repaying the IO mortgage or of all mortgage debt, or the household ceases to exist, i.e., borrowers divorce, initiate new relationships, or die. The figure includes borrowers with IO mortgages originated between 2003 and 2008.

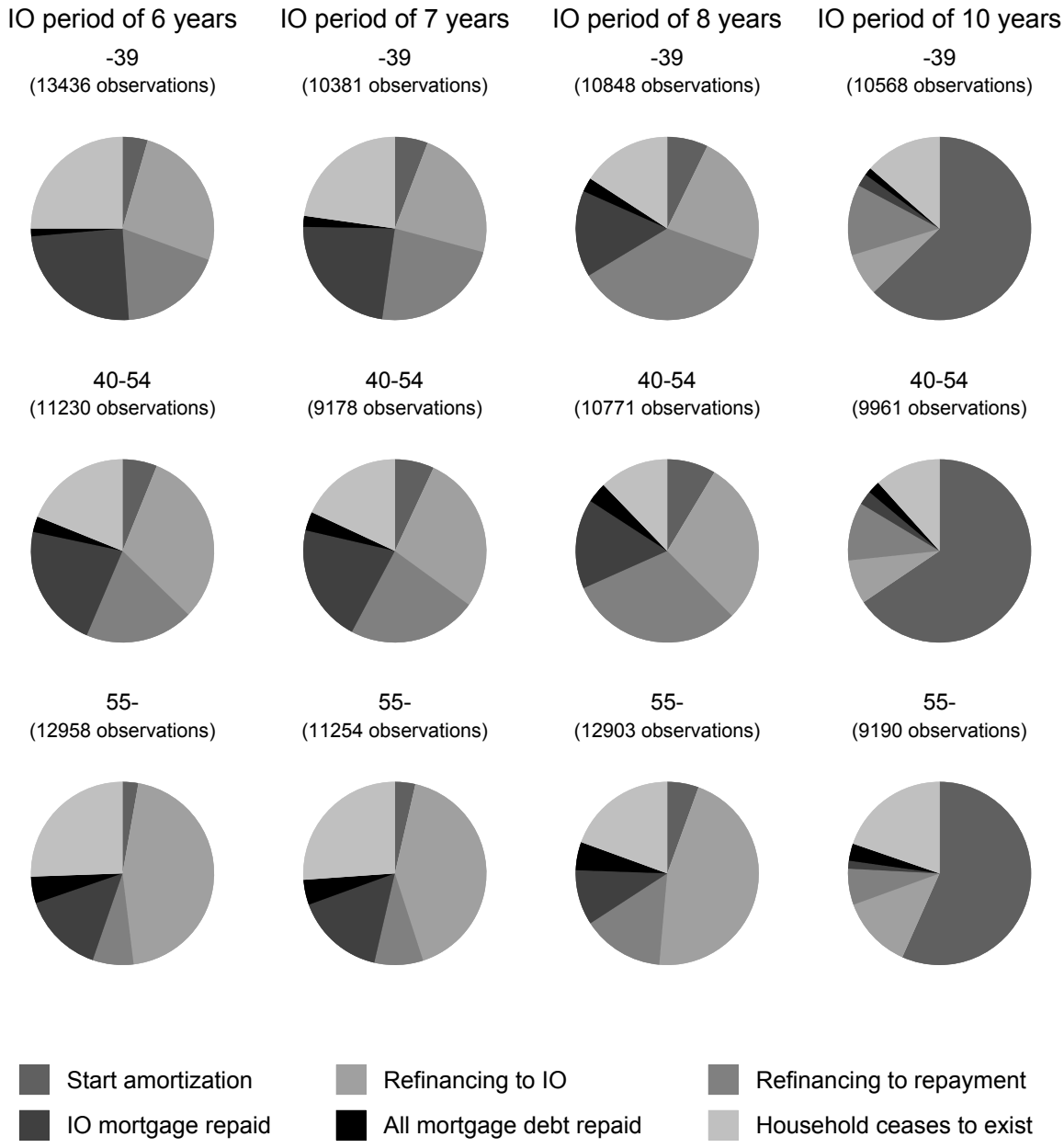
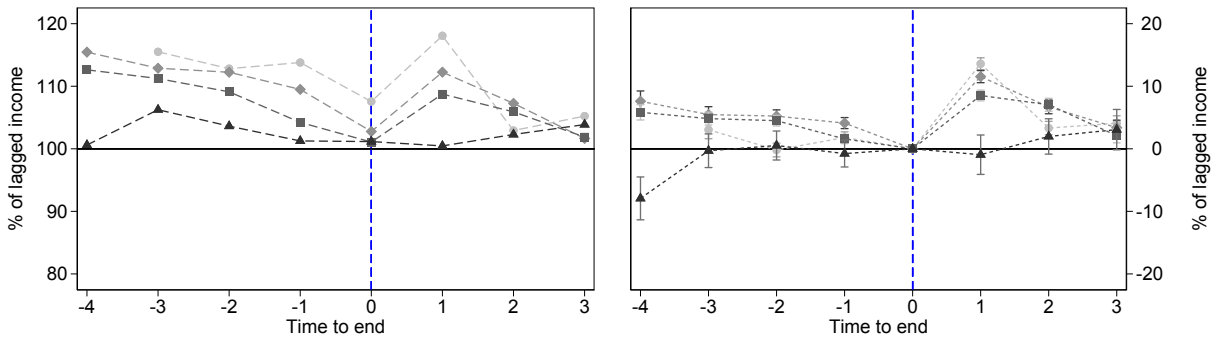
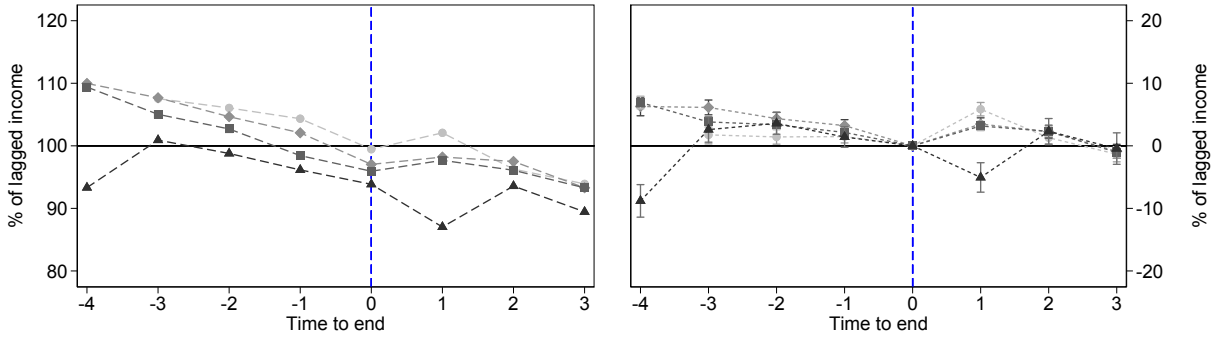


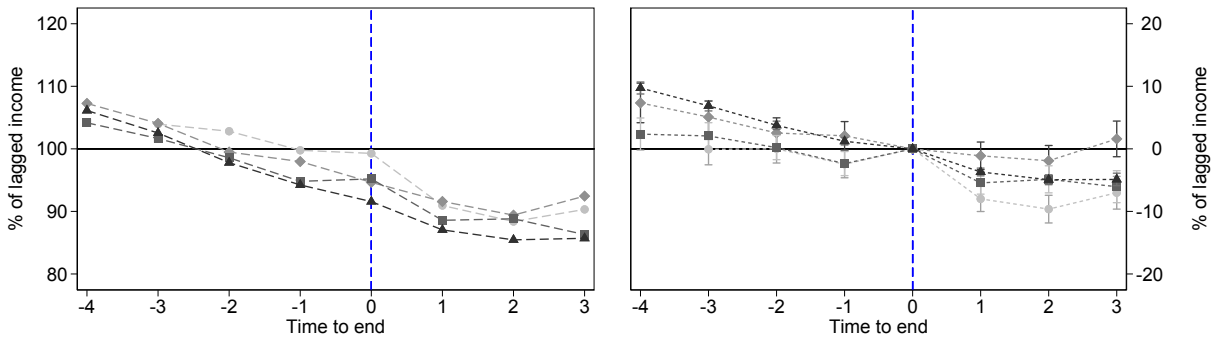
Figure 3: Mortgage choice by age. The figure presents interest-only (IO) borrowers' mortgage choice after IO period of 6, 7, 8, or 10 years. Columns represent IO periods, and the rows represent three age groups, measured at origination of the mortgage. Row 1 corresponds to households below 39 years of age, row 2 between 40 and 54, and row 3 above 55. The end of the IO period can be a result of the mortgage choices; starting amortization, refinancing to a new IO mortgage, refinancing to a repayment mortgage, repaying the IO mortgage or of all mortgage debt, or the household ceases to exist, i.e., borrowers divorce, initiate new relationships, or die. The figure includes borrowers with IO mortgages originated between 2003 and 2008.



(a) Refinance to Interest-Only mortgage



(b) Refinance to repayment mortgage



(c) Start amortization

Figure 4: Consumption effect around end of IO period by mortgage choice. The figure presents average values (first column) and effects of time to end (TTE) (second column) for consumption. Consumption is measured proportional to lagged income. It also includes the 95% confidence interval for effects of TTE. The event study is stated in Eq. (2). For each outcome, we plot effects across various length of interest-only (IO) periods of 6 to 10 years. Panel a refers to IO borrowers that refinance to new IO mortgages, panel b refers to those that refinance to a new repayment mortgage, and panel c refers to those that start amortization. All continuous values are measured in 2020-prices. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008.

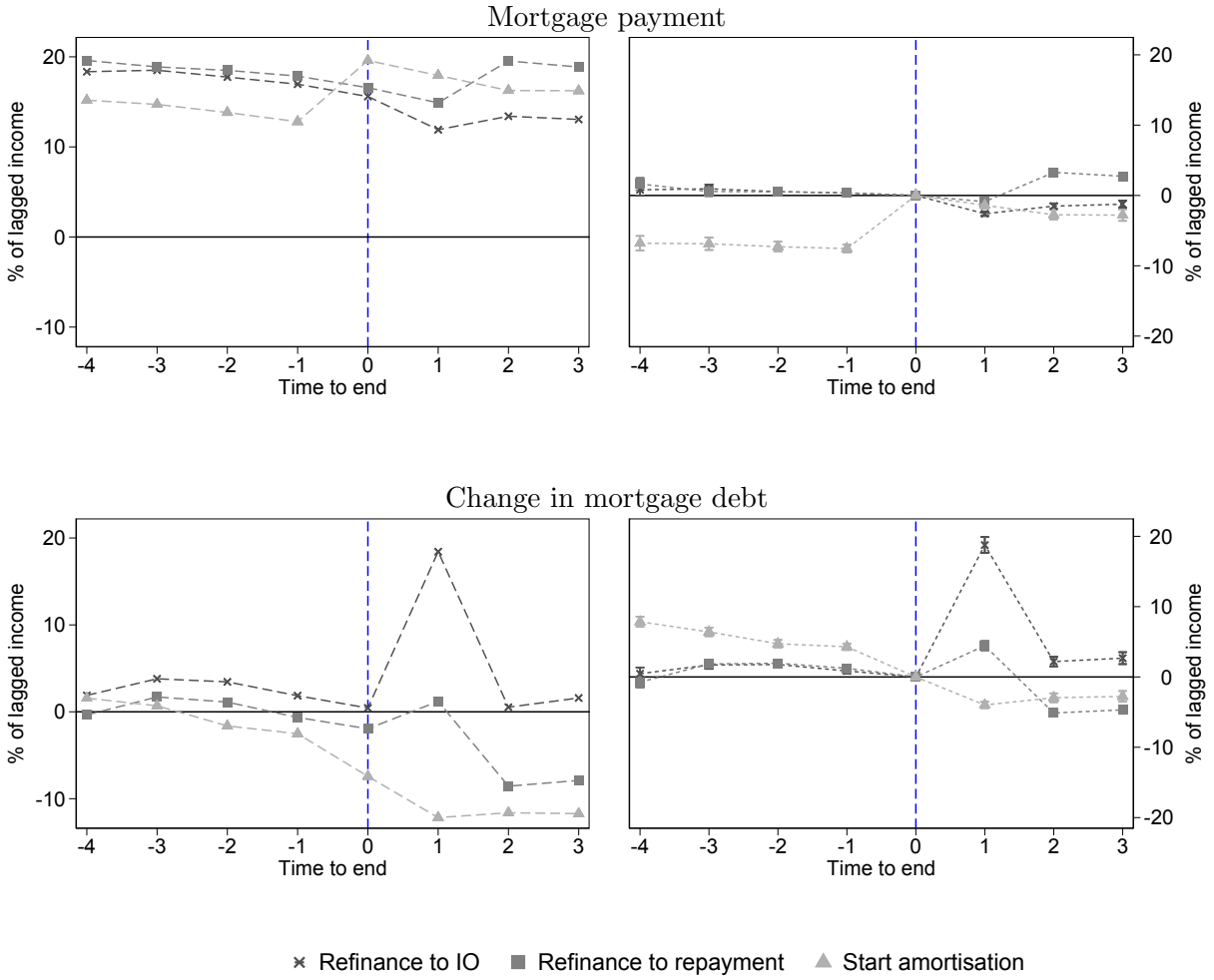


Figure 5: Outcome effect around end of IO period by mortgage choice. The figure presents average values (first column) and effects of time to end (TTE) (second column) for the outcome variables; mortgage payment and annual change in mortgage debt. The outcome variables are measured proportional to lagged income. It also includes the 95% confidence interval for effects of TTE. The event study is stated in Eq. (2). The event study is repeated for interest-only (IO) periods with lengths of 6, 7, 8, and 10 years. We plot the average effects of the various lengths of IO period. The dark gray line with asterisks is based on IO borrowers that refinance to an IO mortgage, the gray line with squares represent IO borrowers that refinance to a repayment mortgage, and the light gray line with triangles IO borrowers that keep the IO mortgage and start amortization. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. All continuous values are measured in 2020-prices. The figure includes borrowers with IO mortgages originated between 2003 and 2008.

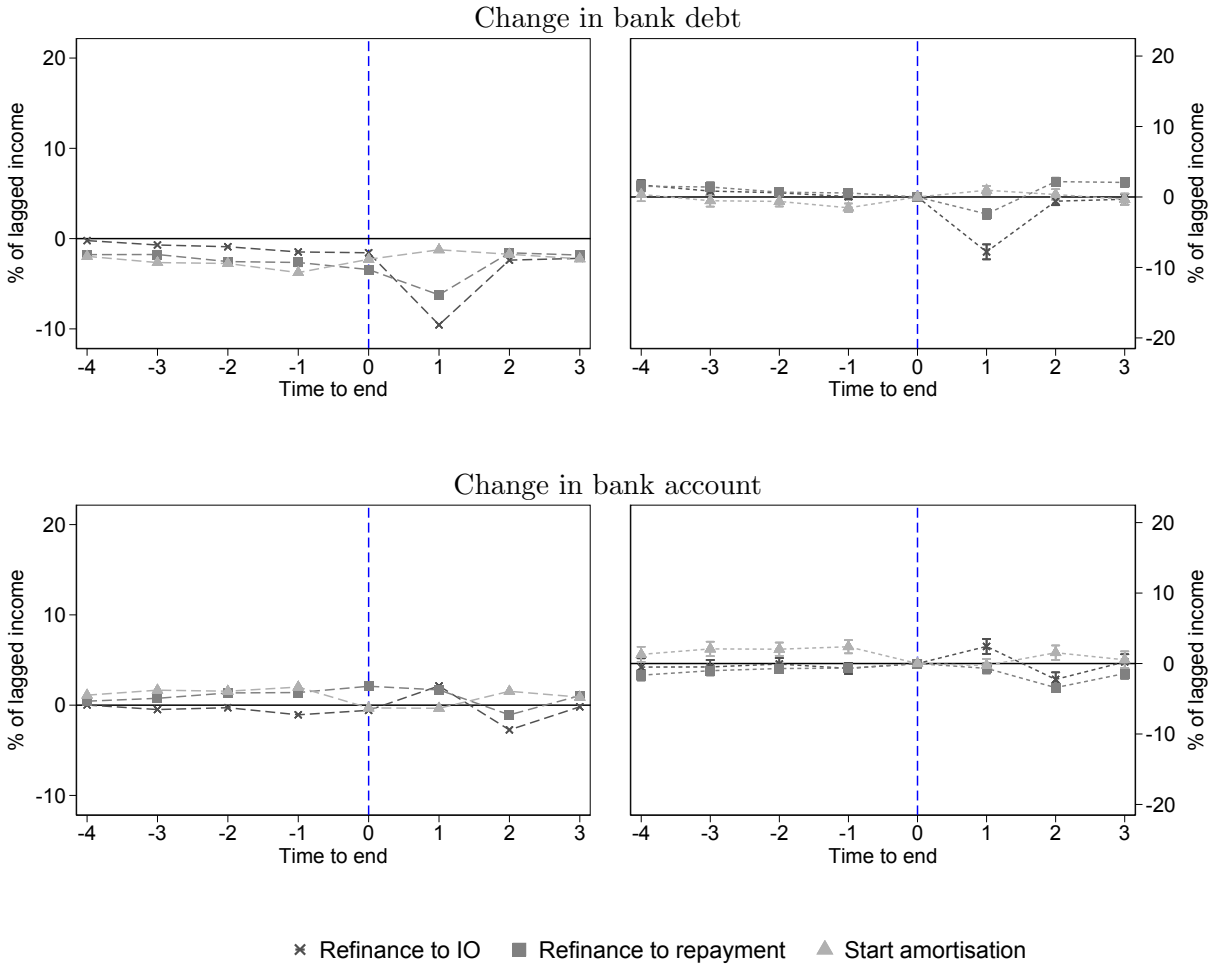


Figure 6: Outcome effect around end of IO period by mortgage choice. The figure presents average values (first column) and effects of time to end (TTE) (second column) for the outcome variables; annual change in bank debt and bank account. The outcome variables are measured proportional to lagged income. It also includes the 95% confidence interval for effects of TTE. The event study is stated in Eq. (2). The event study is repeated for interest-only (IO) periods with lengths of 6, 7, 8, and 10 years. We plot the average effects of the various lengths of IO period. The dark gray line with asterisks is based on IO borrowers that refinance to an IO mortgage, the gray line with squares represent IO borrowers that refinance to a repayment mortgage, and the light gray line with triangles IO borrowers that keep the IO mortgage and start amortization. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. All continuous values are measured in 2020-prices. The figure includes borrowers with IO mortgages originated between 2003 and 2008.

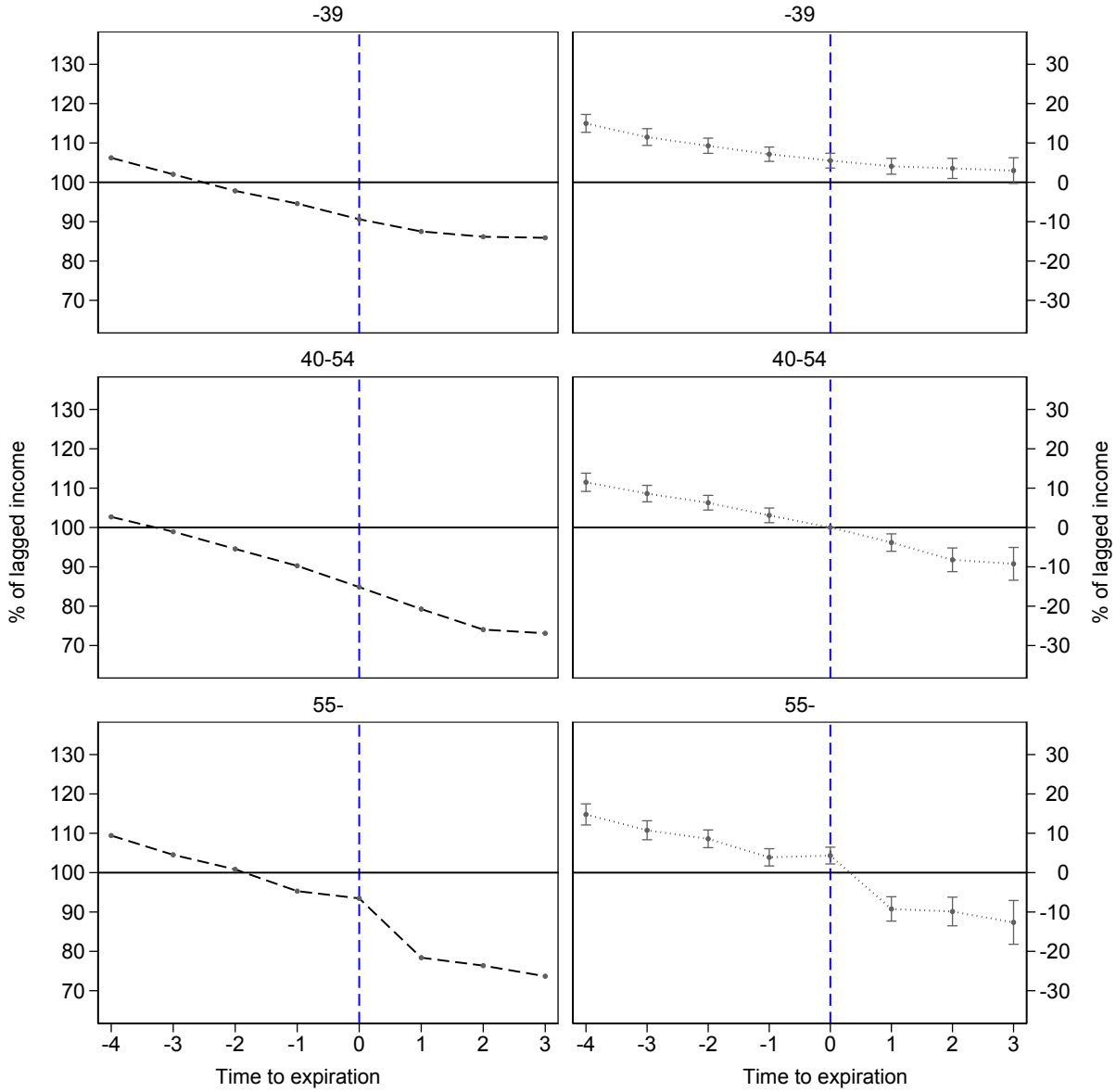


Figure 7: Consumption effect around expiration by age groups. The figure presents average values (left side) and effects of time to expiration (*TTE*) (right side) for consumption. Consumption is measured proportional to lagged income. It also includes the 95% confidence interval for effects of *TTE*. The estimation is based on the event study, stated in Eq. (2). To account for age-differences, dummy variables for age groups are included in the regression - both separately and interacted with *TTE*. Results are plotted across age groups. Age groups corresponds to borrowers' age in the mortgage origination year, and differentiate between households below 39 years of age (first row), between 40-54 (second row), and above 55 (third row). Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and year fixed effect. The figure includes borrowers with interest-only (IO) mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

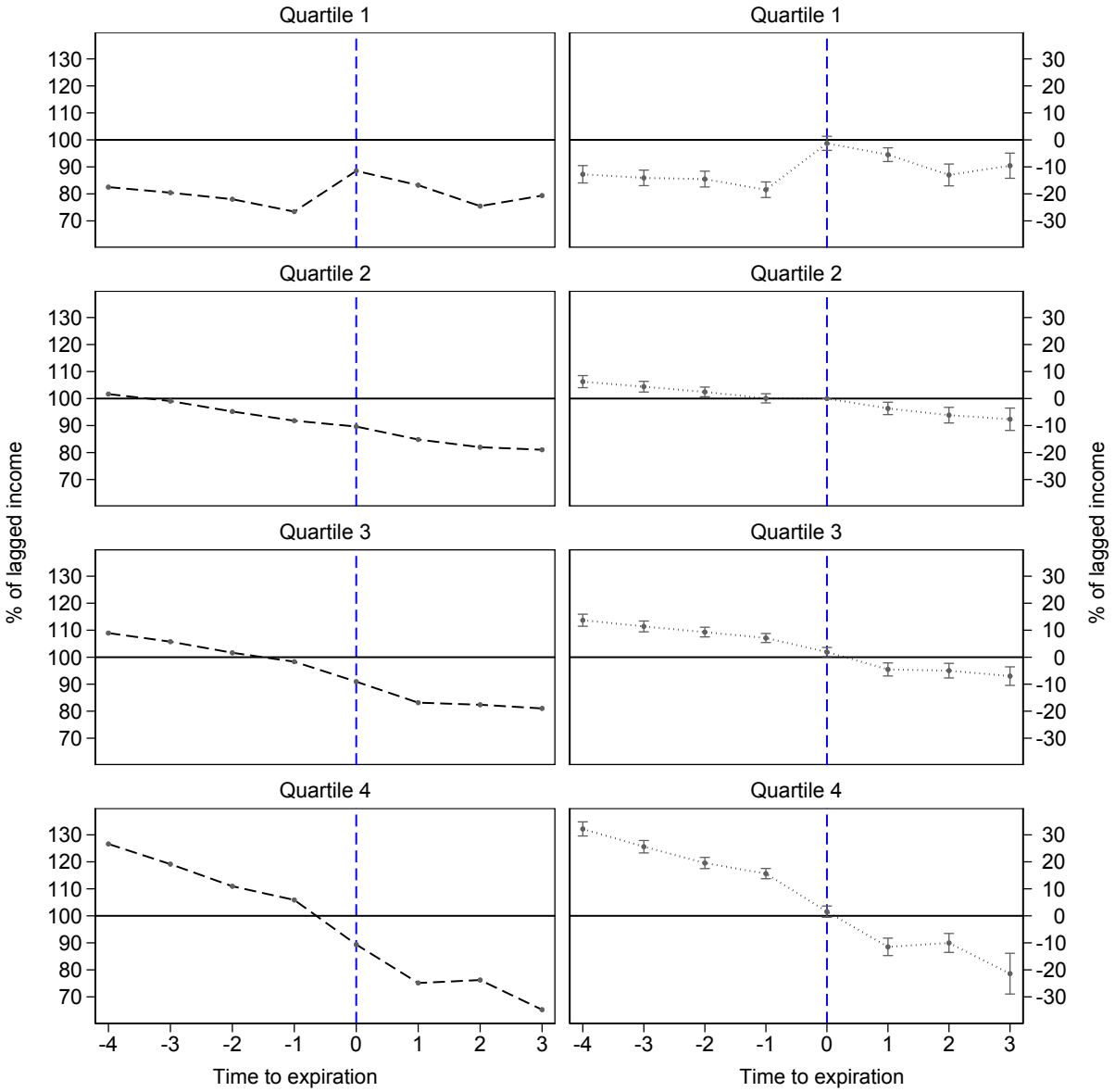
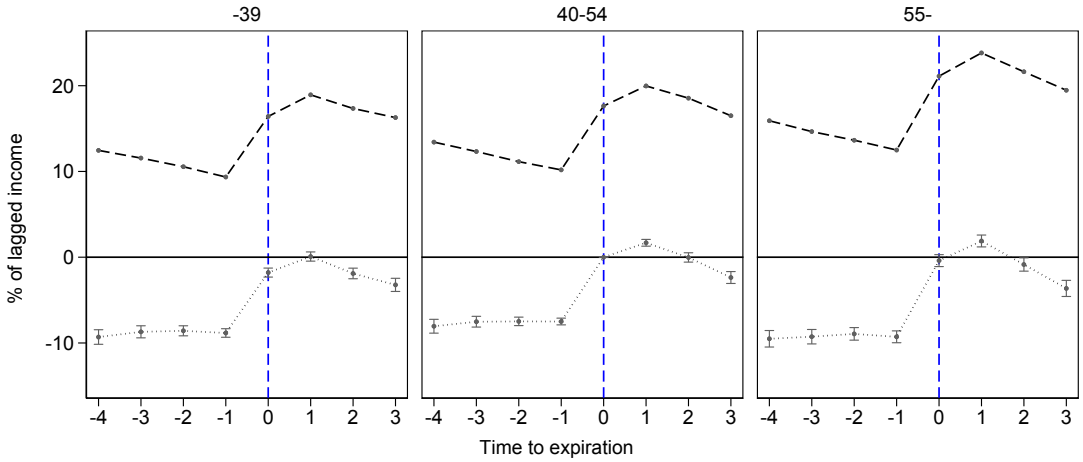
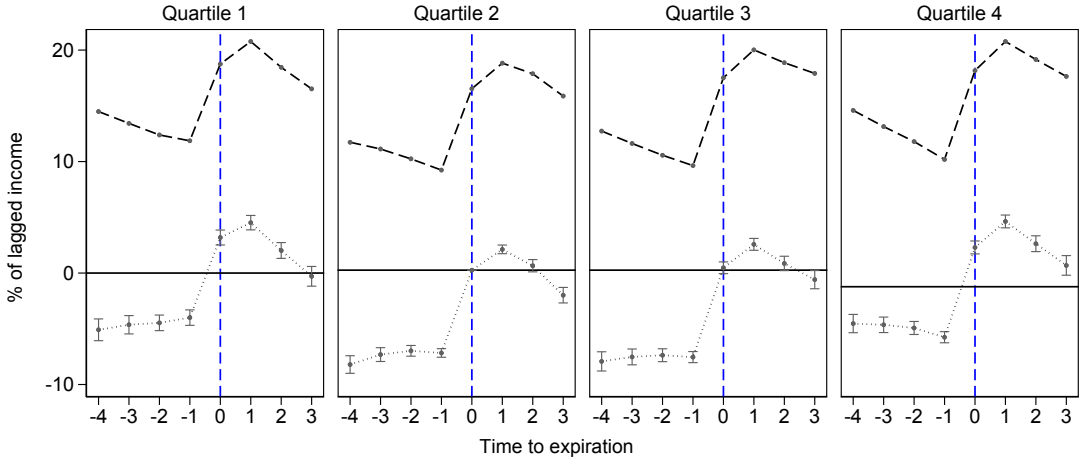


Figure 8: Consumption effect around expiration by quartiles of CTI during IO period. The figure presents average values (left side) and effects of time to expiration (*TTE*) (right side) for consumption. Consumption is measured proportional to lagged income. It also includes the 95% confidence interval for effects of *TTE*. The estimation is based on the event study, stated in Eq. (2). To account for differences in avg. consumption during the interest-only (IO) period, dummy variables for quartiles of average consumption to lagged income (CTI) during the IO period are included in the regression - both separately and interacted with *TTE*. Results are plotted across quartiles of average CTI during the IO period; households within quartile 1 (first row), quartile 2 (second row), quartile 3 (third row), and quartile 4 (fourth row). Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.



(a) By age groups



(b) By quartiles of CTI during IO period

Figure 9: Mortgage payment effect around expiration. The figure presents average values (dashed line) and effects of time to expiration (*TTE*) (dotted line) for mortgage payments, measured proportional to lagged income. It also includes the 95% confidence interval for effects of *TTE*. Results are plotted across age groups corresponding to borrowers' age in the mortgage origination year (panel a) and across quartiles of average consumption to lagged income (CTI) during the interest-only (IO) period (panel b). The estimation is based on the event study, stated in Eq. (2). To account for differences in (a) age and (b) avg. consumption during the IO period, dummy variables for (a) age groups and (b) quartiles of average CTI during the IO period are included in the regression - both separately and interacted with *TTE*. In panel a, age groups differentiate between households below 39 years of age (first column), between 40-54 (second column), and above 55 (third column). In panel b, the first column represents households within quartile 1, second column households within quartile 2, third column households within quartile 3, and fourth column households within quartile 4. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage (only included for panel b), and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

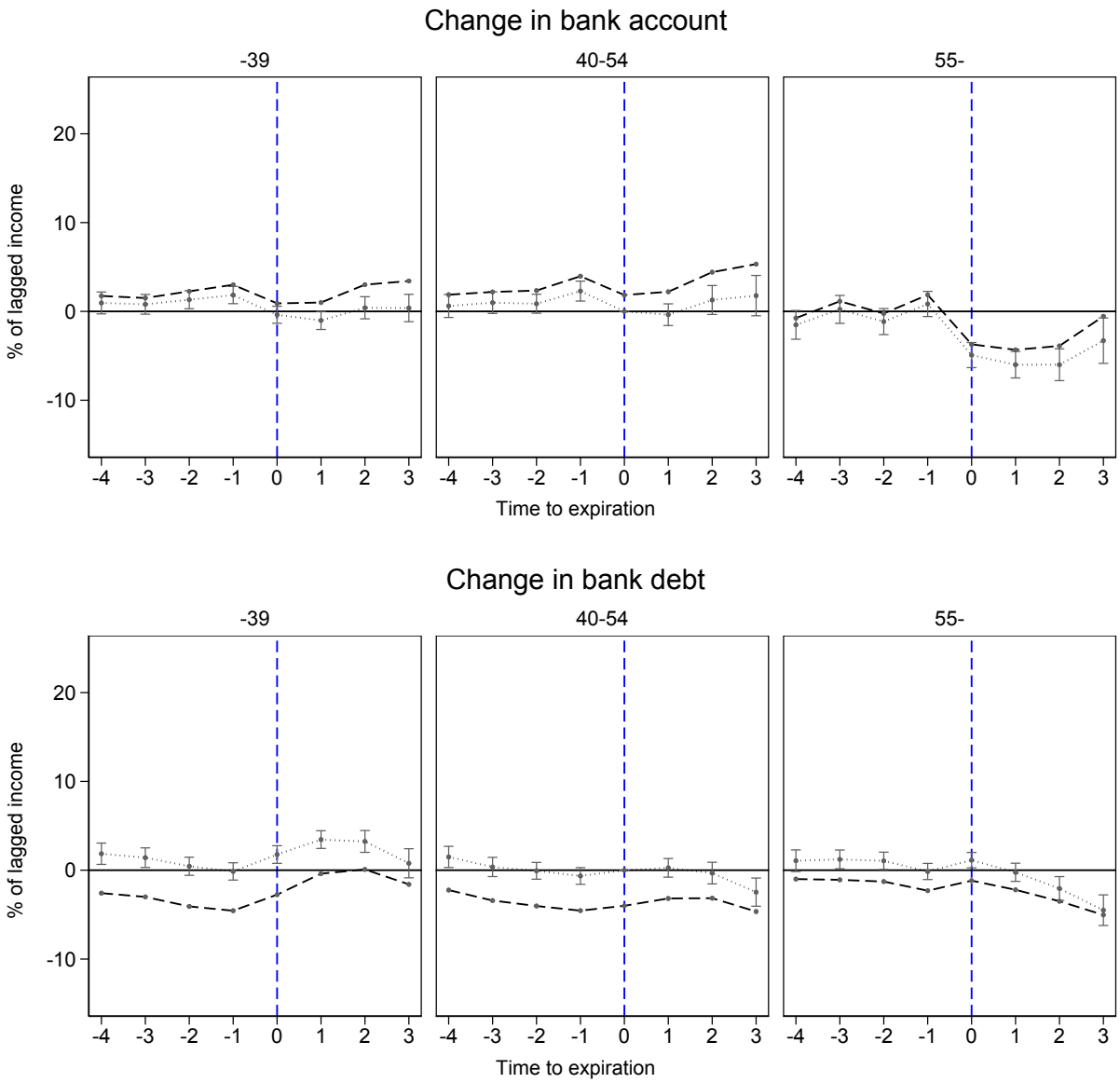


Figure 10: Outcome effect around expiration by age group. The figure presents average values (dashed line) and effects of time to expiration (TTE) (dotted line) for the outcome variables; annual change in bank account and bank debt. The outcome variables are measured proportional to lagged income. It also includes the 95% confidence interval. The estimation is based on the event study, stated in Eq. (2). To account for age-differences, dummy variables for age groups are included in the regression - both separately and interacted with TTE. Results are plotted across age groups. Age groups corresponds to borrowers' age in the mortgage origination year, and differentiate between households below 39 years of age (left), between 40-54 (middle), and above 55 (right). Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and year fixed effect. The figure includes borrowers with interest-only (IO) mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

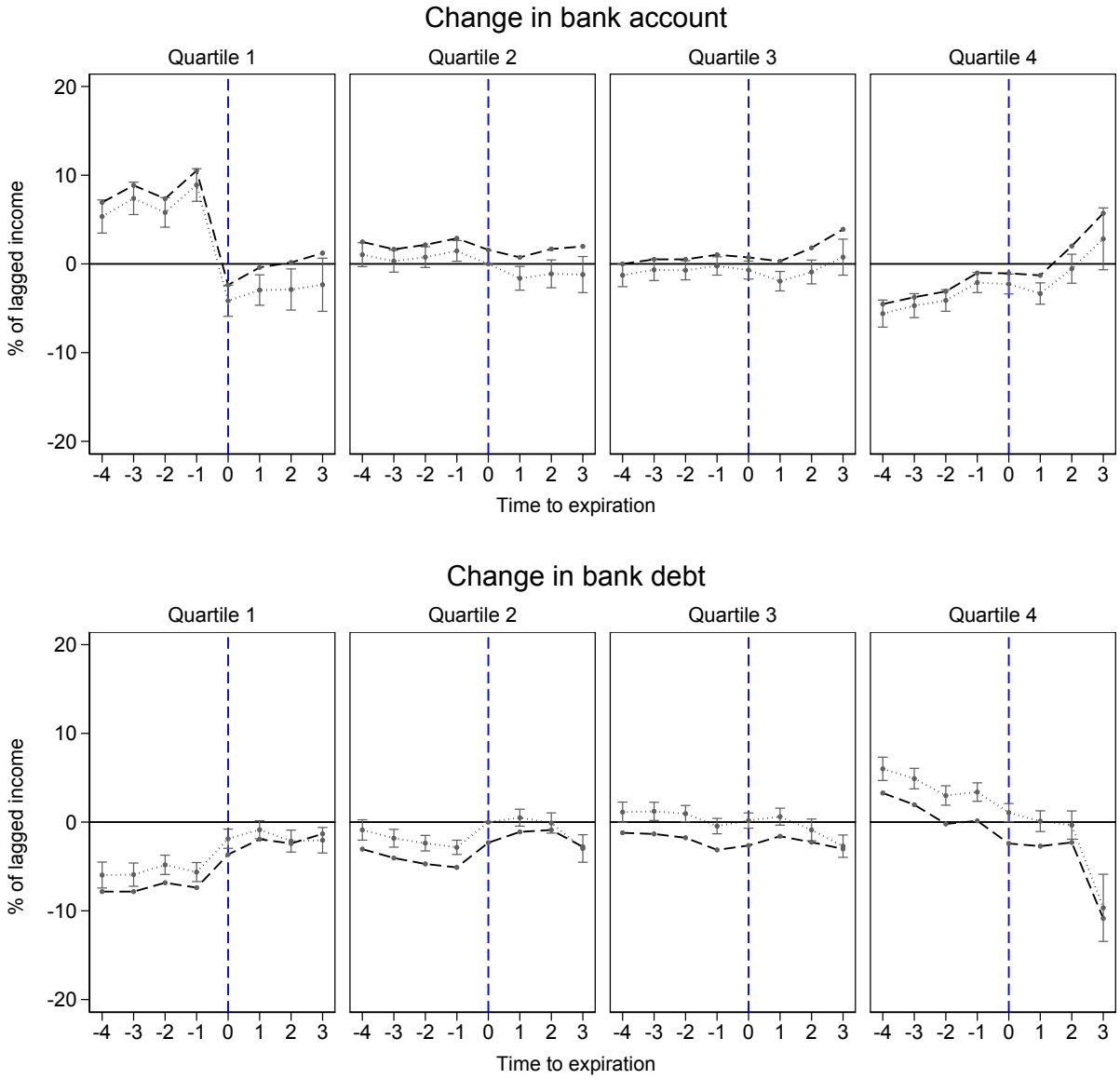


Figure 11: Outcome effect around expiration by quartiles of CTI during IO period. The figure presents average values (dashed line) and effects of time to expiration (TTE) (dotted line) for the outcome variables; annual change in bank account and bank debt. The outcome variables are measured proportional to lagged income. It also includes the 95% confidence interval. The estimation is based on the event study, stated in Eq. (2). To account for differences in avg. consumption during the interest-only (IO) period, dummy variables for quartiles of average consumption to lagged income (CTI) during the IO period are included in the regression - both separately and interacted with TTE. Results are plotted across quartiles of average CTI during the IO period; households within quartile 1 (first column), quartile 2 (second column), quartile 3 (third column), and quartile 4 (fourth column). Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

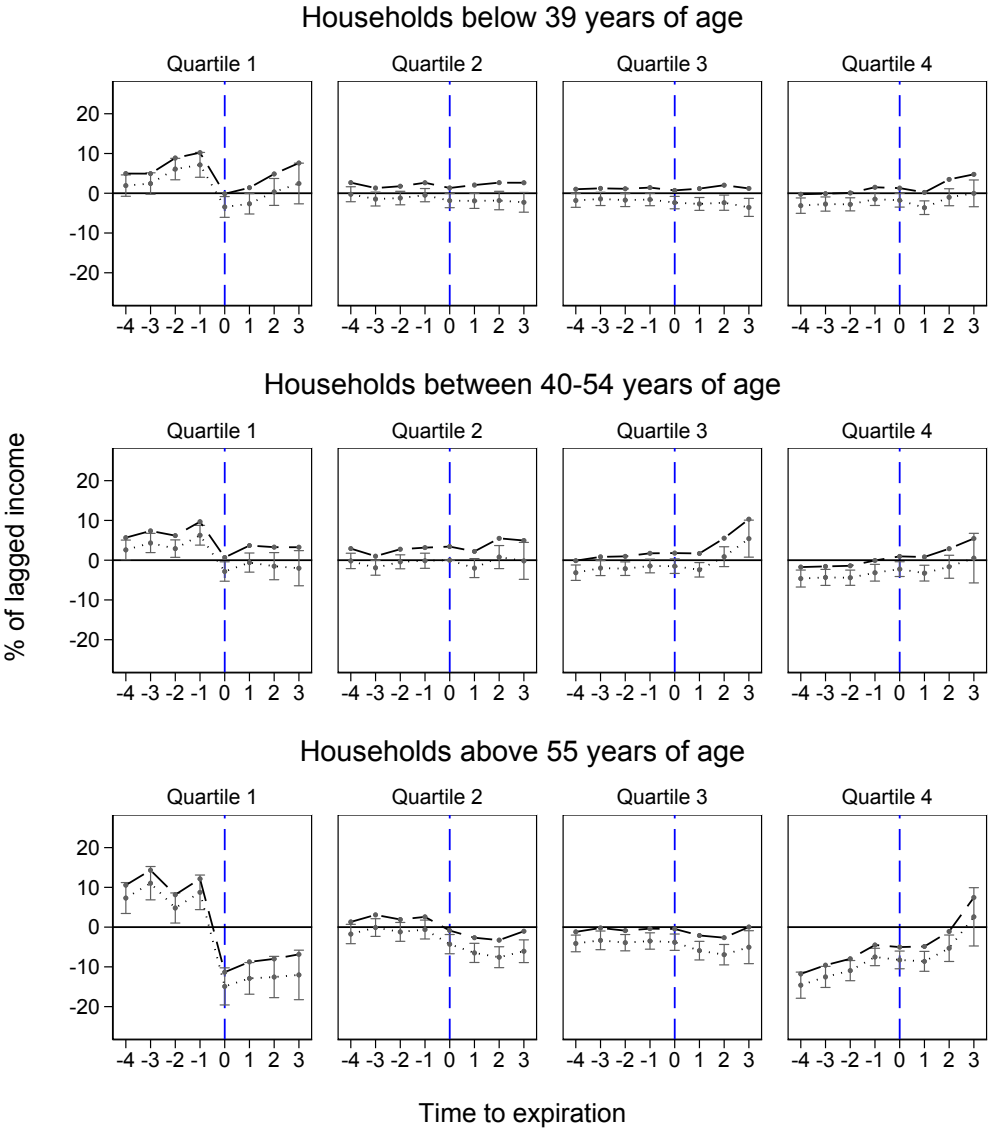


Figure 12: Bank holdings effect around expiration by age groups and quartiles of CTI. The figure presents average values (dashed line) and effects of time to expiration (*TTE*) (dotted line) for annual change in bank account, measured proportional to lagged income. It also includes the 95% confidence interval. Results are plotted across age groups and across quartiles of average consumption to lagged income (CTI) during the interest-only (IO) period. The estimation is based on the event study, stated in Eq. (2). To account for differences in age and avg. consumption during the IO period, dummy variables for age groups and quartiles of average CTI during the IO period are included in the regression - both separately and interacted with *TTE*. Age groups differentiate between households below 39 years of age at mortgage origination (first row), between 40-54 (second row), and above 55 (third row). The first column represents households within quartile 1, second column households within quartile 2, third column households within quartile 3, and fourth column households within quartile 4. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

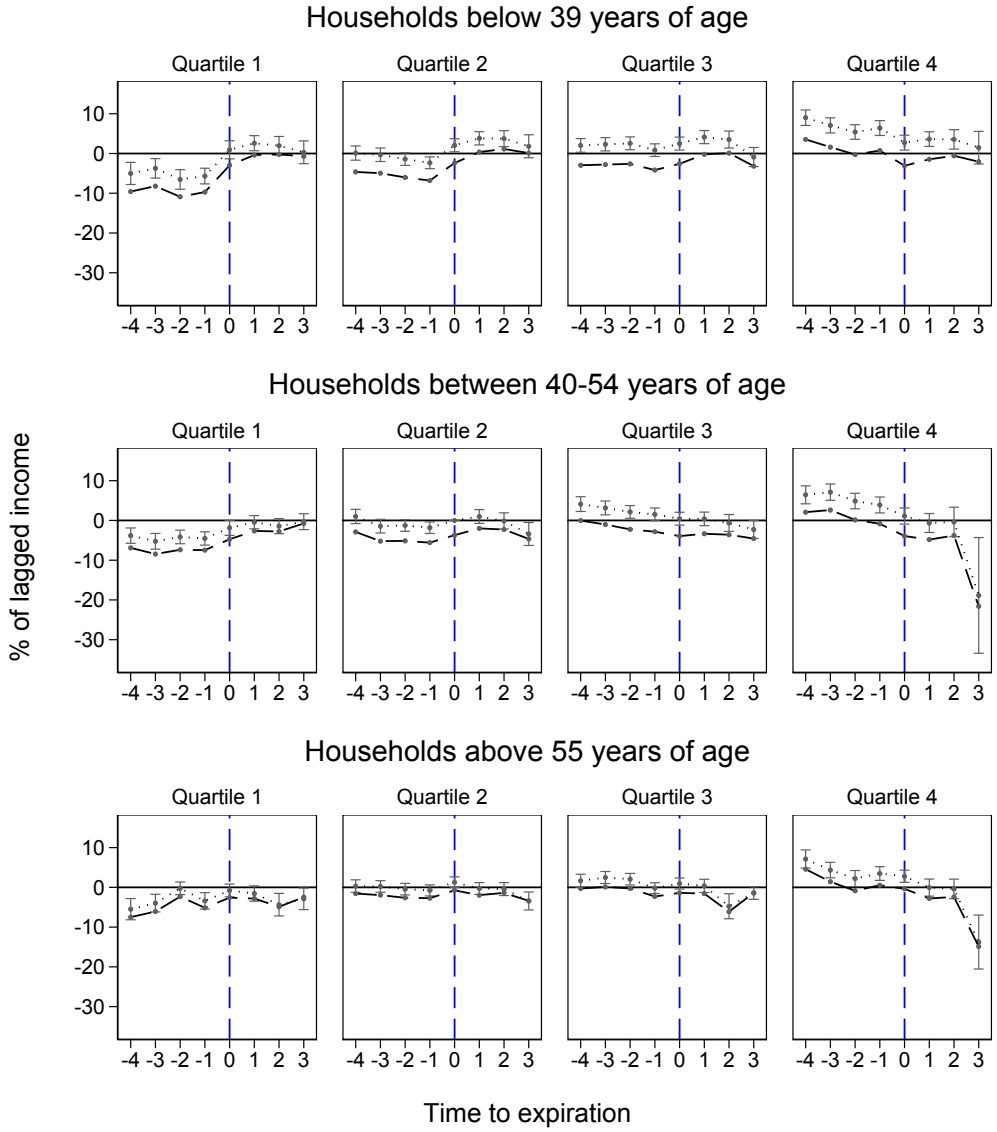


Figure 13: Bank debt effect around expiration by age groups and quartiles of CTI. The figure presents average values (dashed line) and effects of time to expiration (*TTE*) (dotted line) for annual change in bank debt, measured proportional to lagged income. It also includes the 95% confidence interval. Results are plotted across age groups and across quartiles of average consumption to lagged income (CTI) during the interest-only (IO) period. The estimation is based on the event study, stated in Eq. (2). To account for differences in age and avg. consumption during the IO period, dummy variables for age groups and quartiles of average CTI during the IO period are included in the regression - both separately and interacted with *TTE*. Age groups differentiate between households below 39 years of age at mortgage origination (first row), between 40-54 (second row), and above 55 (third row). The first column represents households within quartile 1, second column households within quartile 2, third column households within quartile 3, and fourth column households within quartile 4. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

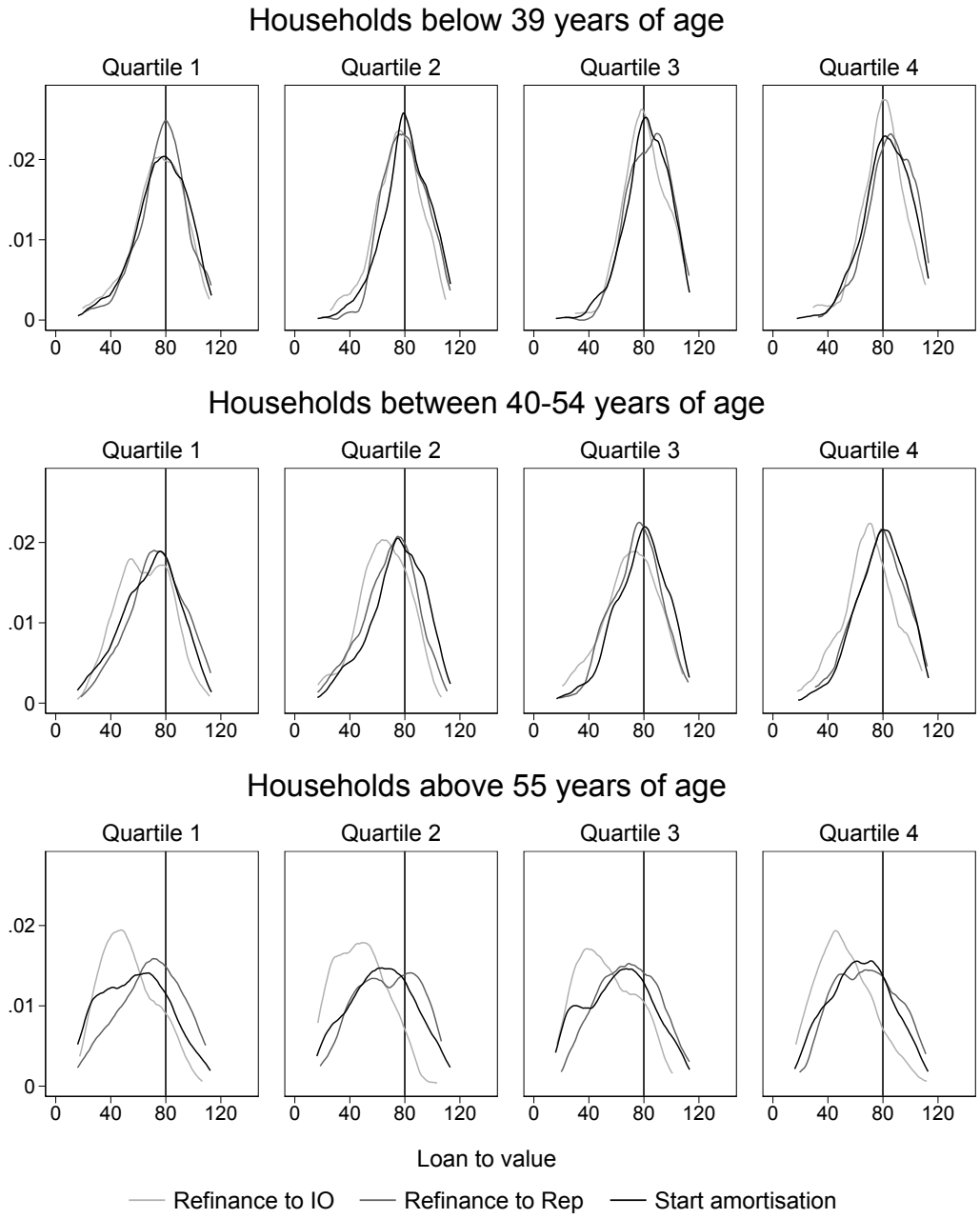


Figure 14: Density of Loan to Value. The figure presents the kernel distribution of Loan to Value, measured one year prior to the expiration of the interest-only (IO) period, by age groups and quartiles of consumption to lagged income (CTI) during IO period. The figure reports Loan to Value separately for IO borrowers that refinance to a new IO mortgage at expiration (light gray), those that refinance to a repayment mortgage (gray), and those that start amortization (dark gray). Age groups are defined in the mortgage origination year, and differentiate between households below 39 years of age (row 1), between 40-54 (row 2), and above 55 (row 3). The first column represents households within quartile 1, second column households within quartile 2, third column households within quartile 3, and fourth column households within quartile 4. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

	(a) Refinance to IO		(b) Refinance to repayment		(c) Start amortisation
	IO period: 7	IO period: 10	IO period: 7	IO period: 10	IO period: 7
Average CTI during IO period	0.033***	-0.009	-0.029***	-0.001	-0.008
	(0.010)	(0.009)	(0.010)	(0.010)	(0.006)
No kids during/No kids after	0.028***	-0.019**	0.009	-0.005	0.004
	(0.011)	(0.009)	(0.010)	(0.009)	(0.007)
No kids during/kids after	0.084***	0.032	0.038	0.045	-0.006
	(0.029)	(0.044)	(0.027)	(0.044)	(0.018)
Kids during/No kids after	-0.006	-0.013	0.021*	0.000	-0.007
	(0.012)	(0.009)	(0.011)	(0.009)	(0.007)
Retires during IO period	0.055***	0.041***	0.050***	0.029***	-0.002
	(0.010)	(0.008)	(0.013)	(0.010)	(0.008)
Unemployed during IO period	-0.021*	-0.012	-0.048***	-0.011	0.007
	(0.011)	(0.008)	(0.010)	(0.008)	(0.008)
Loan to value (%)	-0.000	-0.000	0.001***	0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Loan to value above 80%	-0.046***	-0.010	-0.008	-0.010	0.005
	(0.012)	(0.010)	(0.010)	(0.009)	(0.007)
Adjustable rate mortgage	-0.239***	-0.134***	-0.386***	-0.296***	0.028***
	(0.008)	(0.008)	(0.009)	(0.010)	(0.005)
Zealand	-0.152***	-0.099***	-0.059***	-0.057***	-0.019***
	(0.010)	(0.008)	(0.009)	(0.008)	(0.007)
Southern Denmark	-0.095***	-0.119***	-0.053***	-0.077***	-0.039***
	(0.009)	(0.008)	(0.009)	(0.008)	(0.006)
Central Jutland	-0.036***	-0.083***	-0.022**	-0.063***	-0.027***
	(0.010)	(0.009)	(0.010)	(0.009)	(0.007)
Northern Jutland	-0.049***	-0.119***	-0.030**	-0.074***	-0.029***
	(0.013)	(0.010)	(0.013)	(0.011)	(0.009)
Income growth over 3 year	-0.118**	-0.077*	0.030	0.140***	0.044
	(0.051)	(0.042)	(0.051)	(0.043)	(0.033)
Stock market participation	0.044***	0.008	0.026***	0.006	0.009
	(0.008)	(0.007)	(0.008)	(0.008)	(0.006)
Risky Asset Share	0.016	0.047***	-0.031	0.006	0.000
	(0.018)	(0.013)	(0.019)	(0.016)	(0.012)
Observations	19,568	14,360	16,073	14,510	12,593
Pseudo R-squared	0.178	0.203	0.197	0.171	0.054

Standard errors in parentheses

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table 1: Probit of mortgage choices. The table presents average partial effects of probit estimation on the mortgage choice at the end of the interest-only (IO) period, as stated in Eq. (1). The dependent variable is a dummy variable that takes a value of 1 for IO borrowers that (a) refinance to an IO mortgage, (b) refinance to a repayment mortgage, or (c) start amortization early, and a value of 0 for IO borrowers that start amortization after 10 years. We run the probit estimation separately for each length of IO period (7 and 10 years) and each mortgage choice (a, b, and c). To ensure comparable controls, mortgage (and household) specific controls are measured one (and two) years prior to the base year, i.e., the year corresponding to the end of IO period, where refinancing or early amortization happens. Other controls included in the selection, but not reported, are origination year, age-group dummies, number of adult residents, dummies for kids living at home (in IO period and/or after), male, single, income, and bank holdings. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008.

Mortgage payments	-39	40-54	55-
Expired	0.077***	0.080***	0.093***
	(0.002)	(0.003)	(0.004)
Observations	25,095	26,536	23,608
R-squared	0.299	0.270	0.280
Adj. R-squared	0.299	0.270	0.280

Consumption	-39	40-54	55-
Expired	-0.028***	-0.055***	-0.059***
	(0.008)	(0.009)	(0.011)
Observations	25,095	26,536	23,608
R-squared	0.043	0.050	0.053
Adj. R-squared	0.042	0.049	0.052

Standard errors in parentheses

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table 2: Average effect of amortization period by age groups. The table presents the average change in consumption before and after the interest-only (IO) period expires. Each column presents the consumption effect for each age group corresponding to the borrowers' age at mortgage origination. The consumption effect is based on the event study, specified in Eq. (2), but with a dummy *(Expired)* indicating the four years before the IO period expires vs. four years after instead of *TTE*, and it is estimated separately for each age group. The table also presents robust standard errors (clustered at the household level). Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and year fixed effect. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

Mortgage payments	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Expired	0.072***	0.072***	0.085***	0.106***
	(0.004)	(0.003)	(0.003)	(0.004)
Observations	18,037	19,258	19,208	18,732
R-squared	0.207	0.266	0.314	0.298
Adj. R-squared	0.206	0.265	0.314	0.297

Consumption	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Expired	0.135***	-0.029***	-0.092***	-0.171***
	(0.017)	(0.008)	(0.009)	(0.011)
Observations	18,037	19,258	19,208	18,732
R-squared	0.018	0.041	0.086	0.123
Adj. R-squared	0.017	0.040	0.085	0.122

Standard errors in parentheses

$^{*}p < 0.10,^{**}\, p < 0.05,^{***}\, p < 0.01$

Table 3: Average effect of amortization period by quartiles of CTI. The table presents the average change in consumption before and after the interest-only (IO) period expires. Each column presents the consumption effect for each quartile of average consumption to lagged income (CTI) during the IO period. The consumption effect is based on the event study, specified in Eq. (2), but with a dummy *(Expired)* indicating the four years before the IO period expires vs. four years after instead of *TTE*, and it is estimated separately for each quartile of CTI. The table also presents robust standard errors (clustered at the household level). Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and year fixed effect. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

	-39		40-54		55-	
Dependent variable	First Stage *Mortgage payment*	2SLS *Consumption*	First Stage *Mortgage payment*	2SLS *Consumption*	First Stage *Mortgage payment*	2SLS *Consumption*
Expired	0.077***		0.080***		0.093***	
	(0.002)		(0.003)		(0.004)	
Mortgage payments		-0.362***		-0.690***		-0.631***
		(0.104)		(0.112)		(0.118)
Observations	25,095	25,095	26,536	26,536	23,608	23,608
R-squared	0.299	0.043	0.270	0.035	0.280	0.035
Adj. R-squared	0.299	0.042	0.270	0.034	0.280	0.035

Standard errors in parentheses

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table 4: Elasticity by age groups. The table presents coefficients and robust standard errors (clustered at the household level) from the 2SLS estimation, stated in Eq. (3) and (4). Columns represent age groups corresponding to the borrowers' age, measured at mortgage origination. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and year fixed effect. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

	Quartile 1		Quartile 2		Quartile 3		Quartile 4	
Dependent variable	First Stage *Mortgage payment*	2SLS *Consumption*	First Stage *Mortgage payment*	2SLS *Consumption*	First Stage *Mortgage payment*	2SLS *Consumption*	First Stage *Mortgage payment*	2SLS *Consumption*
Expired	0.072***		0.072***		0.085***		0.106***	
	(0.004)		(0.003)		(0.003)		(0.004)	
Mortgage payments		1.868***		-0.402***		-1.084***		-1.612***
		(0.255)		(0.110)		(0.104)		(0.116)
Observations	18,037	18,037	19,258	19,258	19,208	19,208	18,732	18,732
R-squared	0.207	.	0.266	0.041	0.314	0.049	0.298	.
Adj. R-squared	0.206	.	0.265	0.040	0.314	0.047	0.297	.

Standard errors in parentheses

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table 5: Elasticity by quartile of CTI. The table presents coefficients and robust standard errors (clustered at the household level) from the 2SLS estimation, stated in Eq. (3) and (4). Columns represent quartiles of avg. CTI during the IO period. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

Change in Bank debt	-39	40-54	55-
Expired	0.023***	0.003	0.003
	(0.005)	(0.004)	(0.003)
Observations	25,095	26,536	23,608
Adj. R-squared	0.015	0.016	0.020
R-squared	0.014	0.015	0.019

Change in Bank account	-39	40-54	55-
Expired	-0.025***	-0.020***	-0.048***
	(0.004)	(0.005)	(0.008)
Observations	25,095	26,536	23,608
R-squared	0.008	0.006	0.008
Adj. R-squared	0.008	0.005	0.007

Standard errors in parentheses

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table 6: Average effect of amortization period by age groups. The table presents the average change in consumption before and after the interest-only (IO) period expires. Each column presents the consumption effect for each age group corresponding to the borrowers' age at mortgage origination. The consumption effect is based on the event study, specified in Eq. (2), but with a dummy *(Expired)* indicating the four years before the IO period expires vs. four years after instead of *TTE*, and it is estimated separately for each age group. The table also presents robust standard errors (clustered at the household level). Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and year fixed effect. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

Change in Bank account	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Expired	-0.123***	-0.016***	-0.005	0.003
	(0.011)	(0.005)	(0.004)	(0.005)
Observations	18,037	19,258	19,208	18,732
R-squared	0.018	0.005	0.008	0.026
Adj. R-squared	0.017	0.004	0.007	0.024

Change in Bank debt	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Expired	0.028***	0.025***	0.001	-0.015***
	(0.006)	(0.004)	(0.004)	(0.006)
Observations	18,037	19,258	19,208	18,732
R-squared	0.048	0.033	0.013	0.017
Adj. R-squared	0.047	0.032	0.012	0.015

Standard errors in parentheses

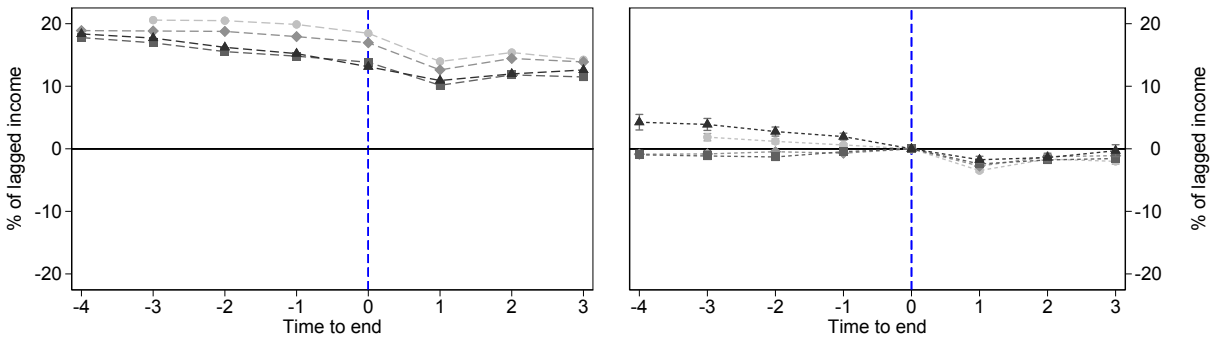
$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table 7: Average effect of amortization period by quartiles of CTI. The table presents the average change in consumption before and after the interest-only (IO) period expires. Each column presents the consumption effect for each quartile of average consumption to lagged income (CTI) during the IO period. The consumption effect is based on the event study, specified in Eq. (2), but with a dummy *(Expired)* indicating the four years before the IO period expires vs. four years after instead of *TTE*, and it is estimated separately for each quartile of CTI. The table also presents robust standard errors (clustered at the household level). Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

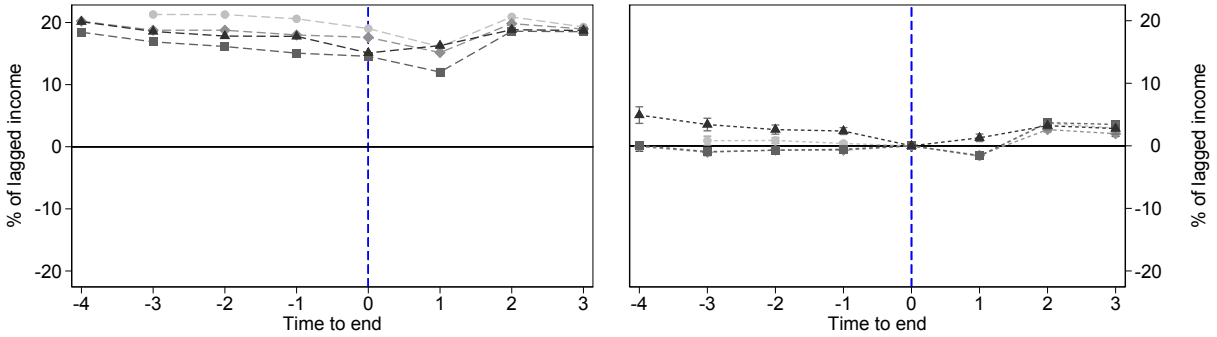
Internet Appendix

The end is near: Consumption and savings decisions at the end of interest-only periods

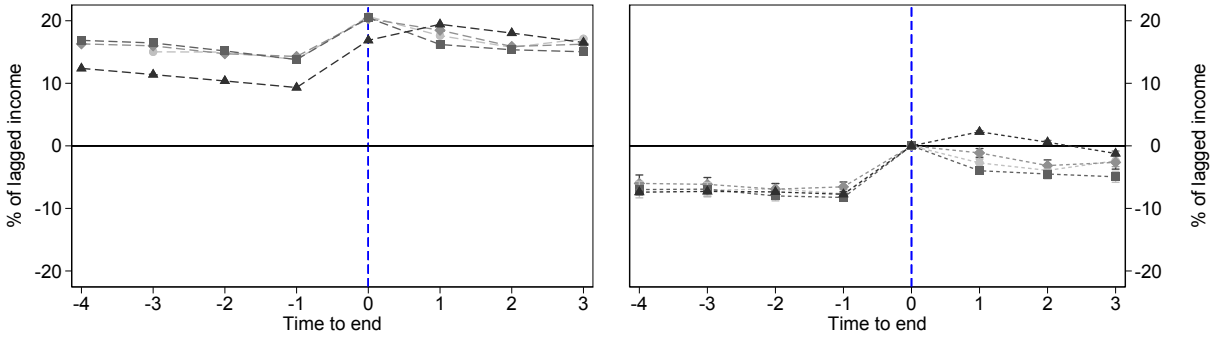
This appendix contains the results of some additional analyses only briefly mentioned in the main text.



(a) Refinance to Interest-Only mortgage

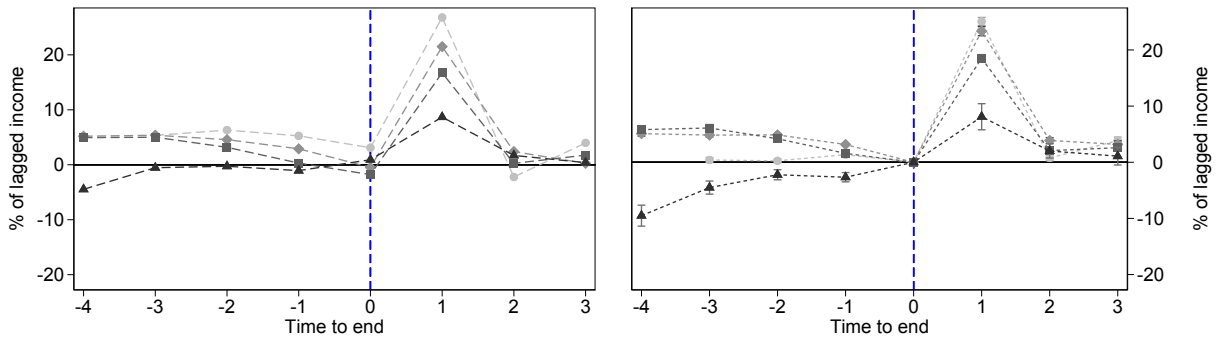


(b) Refinance to repayment mortgage

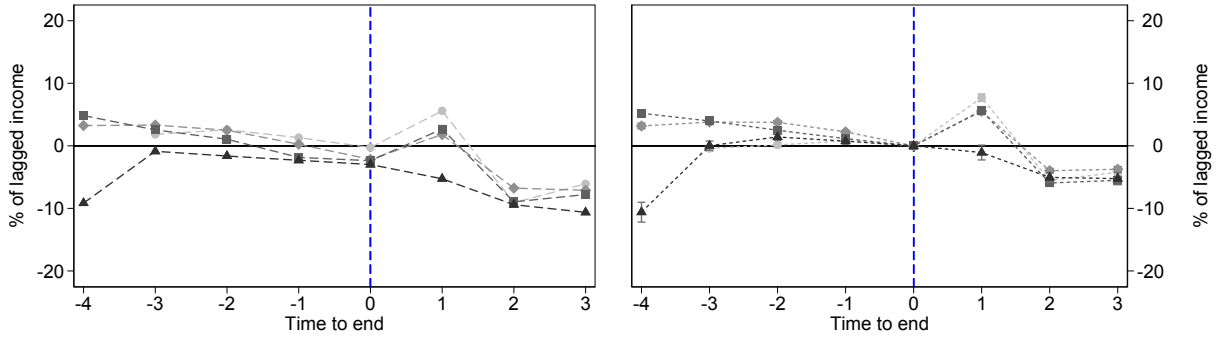


(c) Start amortization

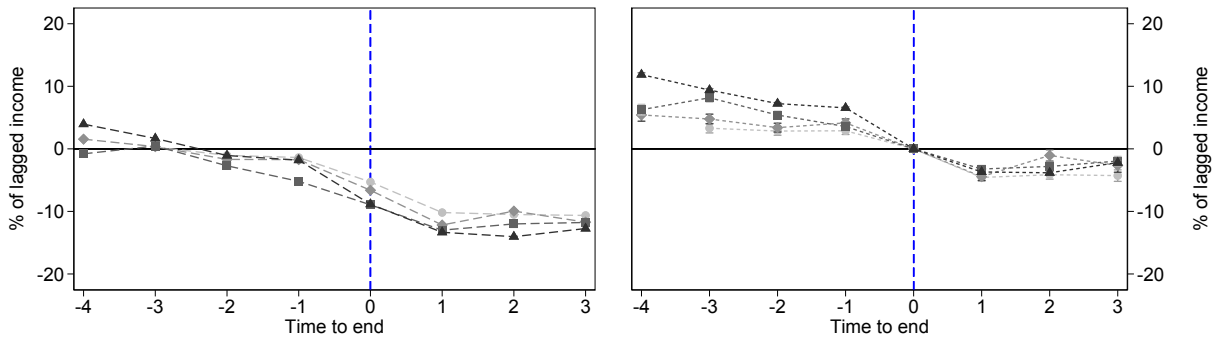
Figure IA.1: Mortgage payment effect around end of IO period by mortgage choice. The figure presents average values (first column) and effects of time to end (TTE) (second column) for mortgage payment, measured proportional to lagged income. It also includes the 95% confidence interval for effects of TTE. The event study is stated in Eq. (2). For each outcome, we plot effects across various length of interest-only (IO) periods of 6 to 10 years. Panel a refers to IO borrowers that refinance to new IO mortgages, panel b refers to those that refinance to a new repayment mortgage, and panel c refers to those that start amortization. All continuous values are measured in 2020-prices. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008.



(a) Refinance to Interest-Only mortgage

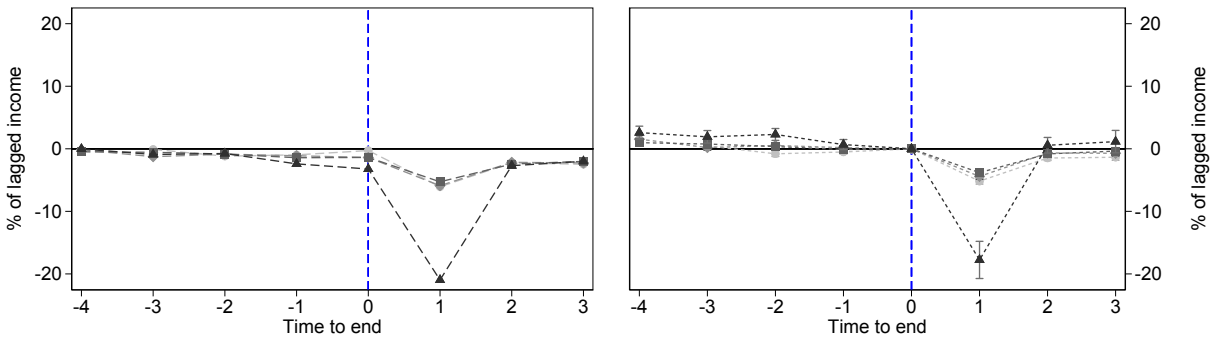


(b) Refinance to repayment mortgage

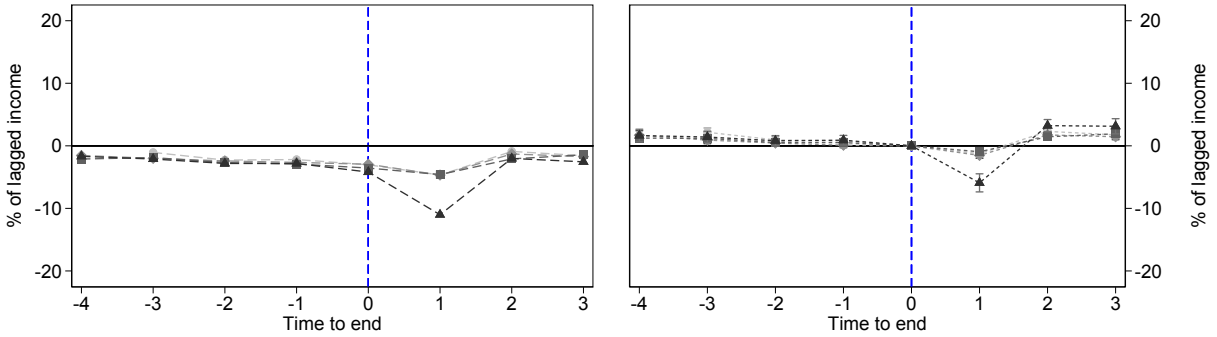


(c) Start amortization

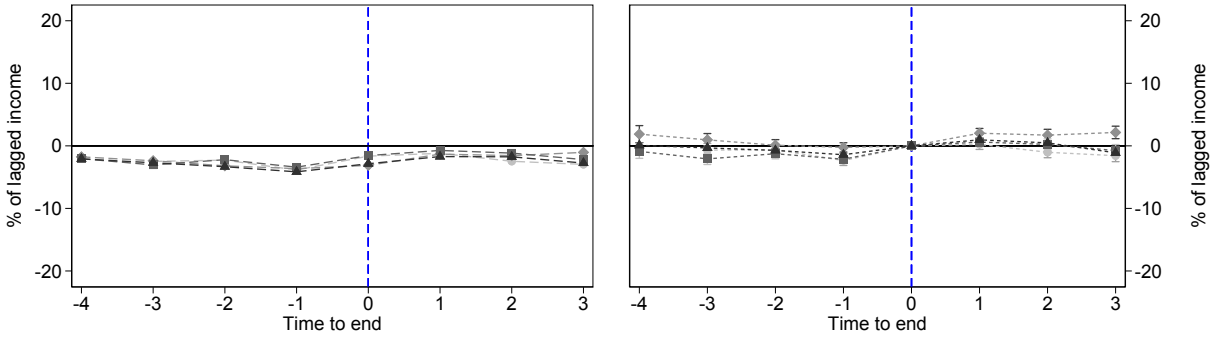
Figure IA.2: Mortgage debt effect around end of IO period by mortgage choice. The figure presents average values (first column) and effects of time to end (*TTE*) (second column) for the annual change in mortgage debt, measured proportional to lagged income. It also includes the 95% confidence interval for effects of *TTE*. The event study is stated in Eq. (2). For each outcome, we plot effects across various length of interest-only (IO) periods of 6 to 10 years. Panel a refers to IO borrowers that refinance to new IO mortgages, panel b refers to those that refinance to a new repayment mortgage, and panel c refers to those that start amortization. All continuous values are measured in 2020-prices. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008.



(a) Refinance to Interest-Only mortgage

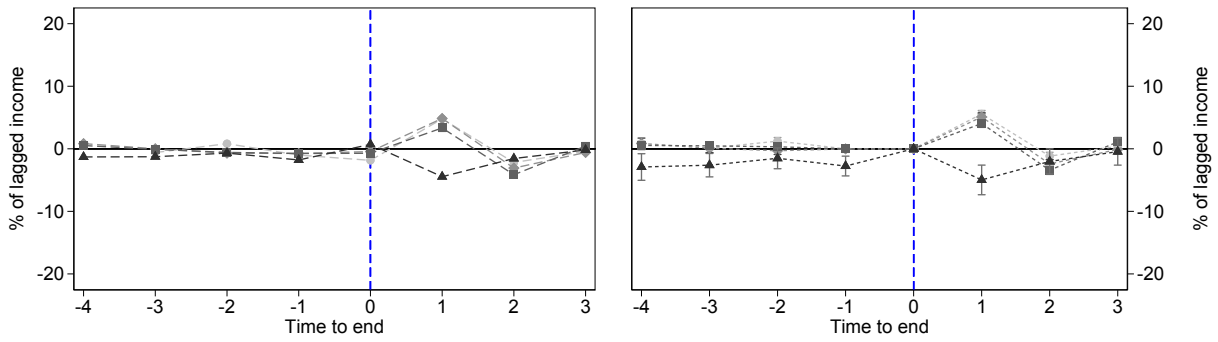


(b) Refinance to repayment mortgage

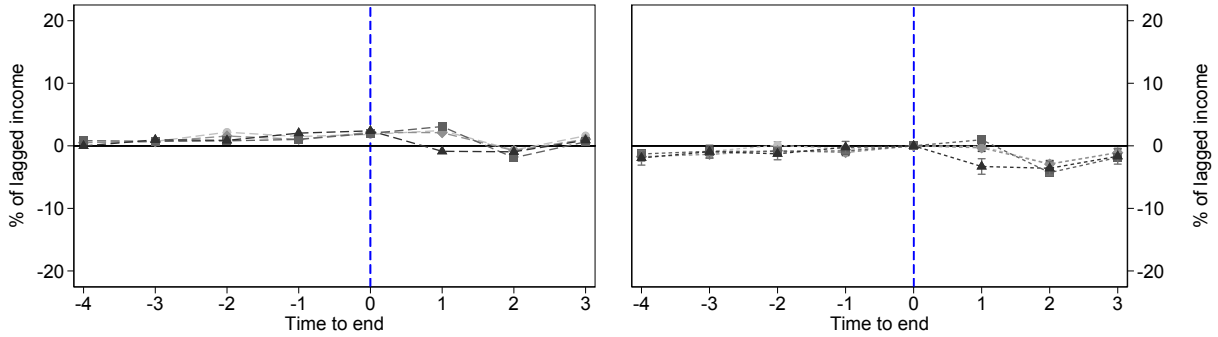


(c) Start amortization

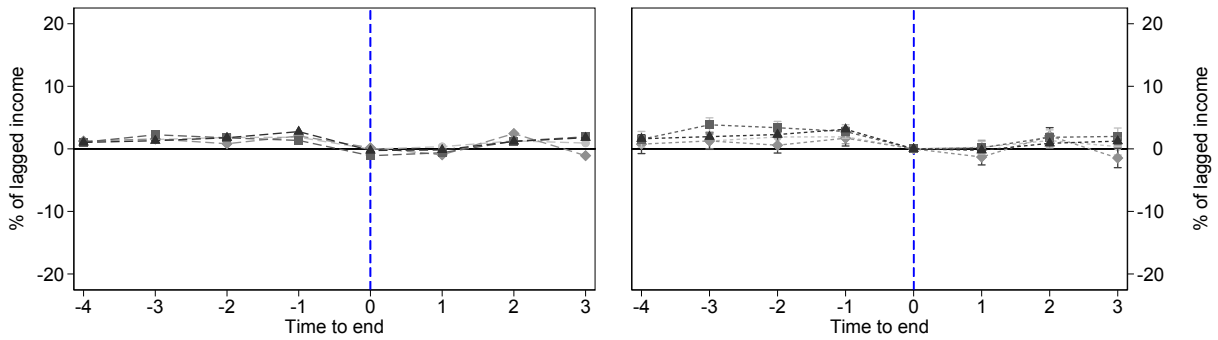
Figure IA.3: Bank debt effect around end of IO period by mortgage choice. The figure presents average values (first column) and effects of time to end (*TTE*) (second column) for the annual change in bank debt, measured proportional to lagged income. It also includes the 95% confidence interval for effects of *TTE*. The event study is stated in Eq. (2). For each outcome, we plot effects across various length of interest-only (IO) periods of 6 to 10 years. Panel a refers to IO borrowers that refinance to new IO mortgages, panel b refers to those that refinance to a new repayment mortgage, and panel c refers to those that start amortization. All continuous values are measured in 2020-prices. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008.



(a) Refinance to Interest-Only mortgage



(b) Refinance to repayment mortgage



(c) Start amortization

Figure IA.4: Bank holdings effect around end of IO period by mortgage choice. The figure presents average values (first column) and effects of time to end (*TTE*) (second column) for the annual change in bank account, measured proportional to lagged income. It also includes the 95% confidence interval for effects of *TTE*. The event study is stated in Eq. (2). For each outcome, we plot effects across various length of interest-only (IO) periods of 6 to 10 years. Panel a refers to IO borrowers that refinance to new IO mortgages, panel b refers to those that refinance to a new repayment mortgage, and panel c refers to those that start amortization. All continuous values are measured in 2020-prices. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008.

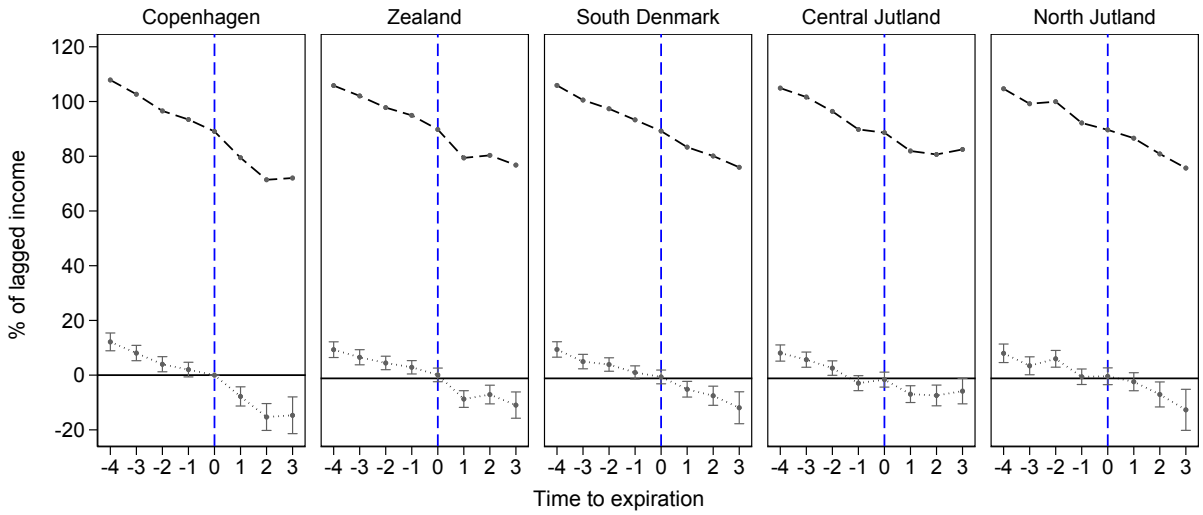


Figure IA.5: Consumption effect around expiration by regions. The figure presents average values (dashed) and effects of time to expiration (TTE) (dotted) for consumption. Consumption is measured proportional to lagged income. It also includes the 95% confidence interval for effects of TTE. Results are plotted across regions; Copenhagen (column 1), Zealand (column 2), South Denmark (column 3), Central Jutland (column 4), and North Jutland (column 5). The estimation is based on the event study, stated in Eq. (2). To account for differences in regions, dummy variables for regions are included in the regression - both separately and interacted with TTE. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, age-group dummies reflecting their age at origination of the interest-only (IO) mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

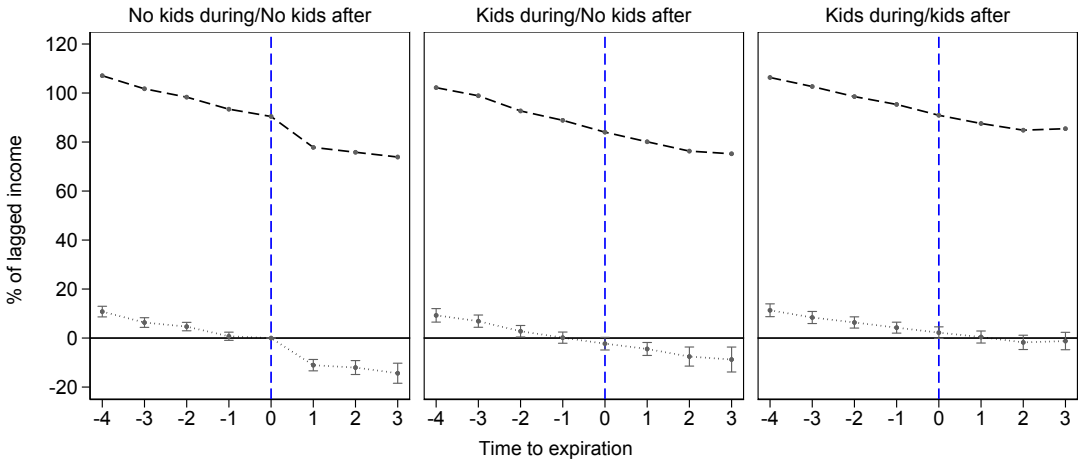


Figure IA.6: Consumption effect around expiration by kids living at home. The figure presents average values (dashed) and effects of time to expiration (TTE) (dotted) for consumption. Consumption is measured proportional to lagged income. It also includes the 95% confidence interval for effects of TTE. Results are plotted across three groups of households: No kids living at home during and after the interest-only (IO) period (column 1), Kids living at home during the IO period and no kids after the IO period (column 2), and kids living at home during and after the IO period (column 3). The estimation is based on the event study, stated in Eq. (2). To account for differences in whether kids live at home during and after the IO period, dummy variables for kids living at home are included in the regression - both separately and interacted with TTE. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

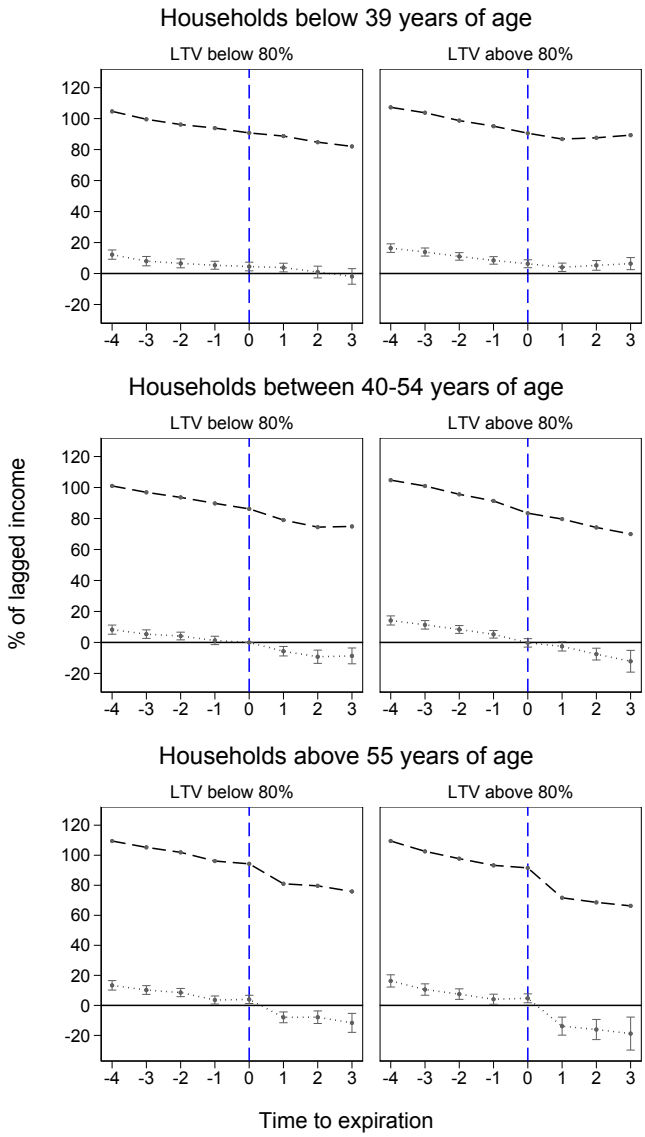


Figure IA.7: Consumption effect around expiration by age groups and loan-to-value. The figure presents average values (dashed) and effects of time to expiration (TTE) (dotted) for consumption. Consumption is measured proportional to lagged income. It also includes the 95% confidence interval for effects of TTE. Results are plotted across age groups and to whether the household has a loan to value (LTV) above 80% or not. Age groups correspond to borrowers' age in the mortgage origination year, and differentiate between households below 39 years of age (row 1), between 40-54 (row 2), and above 55 (row 3). Households with LTV below 80% is represented in column 1, whereas those with LTV above 80% in column 2. The estimation is based on the event study, stated in Eq. (2). To account for differences in age and LTV, dummy variables for age groups and LTV above 80% are included in the regression - both separately and interacted with TTE. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the interest-only (IO) mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

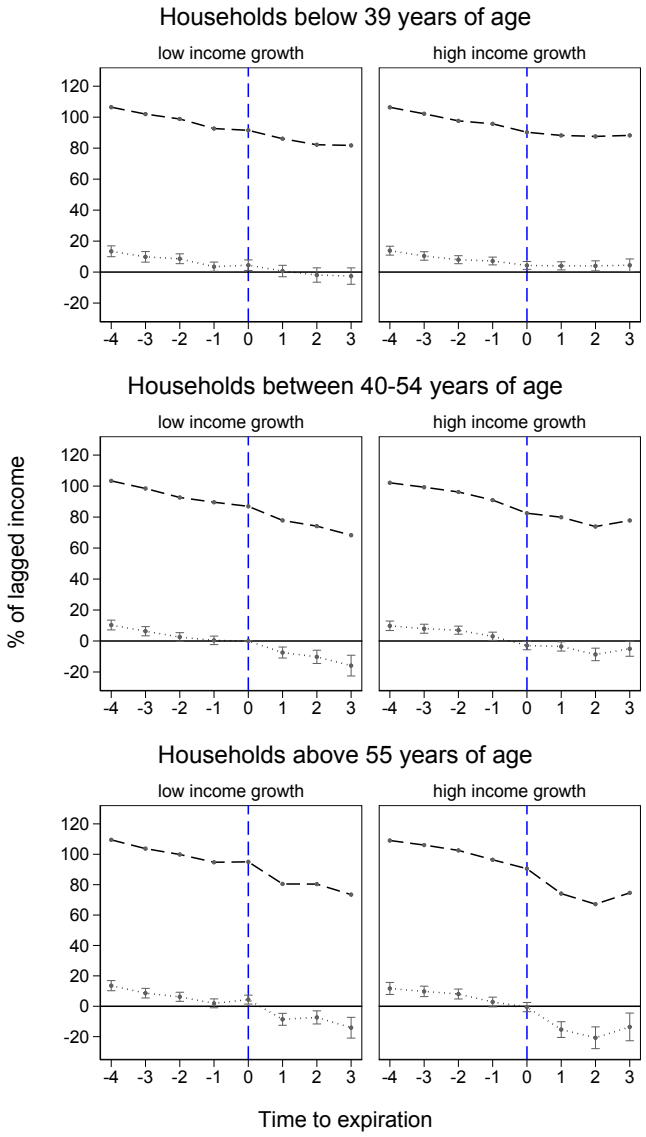


Figure IA.8: Consumption effect around expiration by income growth. The figure presents average values (dashed) and effects of time to expiration (TTE) (dotted) for consumption. Consumption is measured proportional to lagged income. It also includes the 95% confidence interval for effects of TTE. Results are plotted across age groups and low/high income growth. Age groups correspond to borrowers' age in the mortgage origination year, and differentiate between households below 39 years of age (row 1), between 40-54 (row 2), and above 55 (row 3). Households with low (high) income growth is defined as having an average annual income growth during the interest-only (IO) period below (above) the median. The first column represents households with low income growth, the second column those with high income growth. The estimation is based on the event study, stated in Eq. (2). To account for differences in age and income growth, dummy variables for age groups and high income growth are included in the regression - both separately and interacted with TTE. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

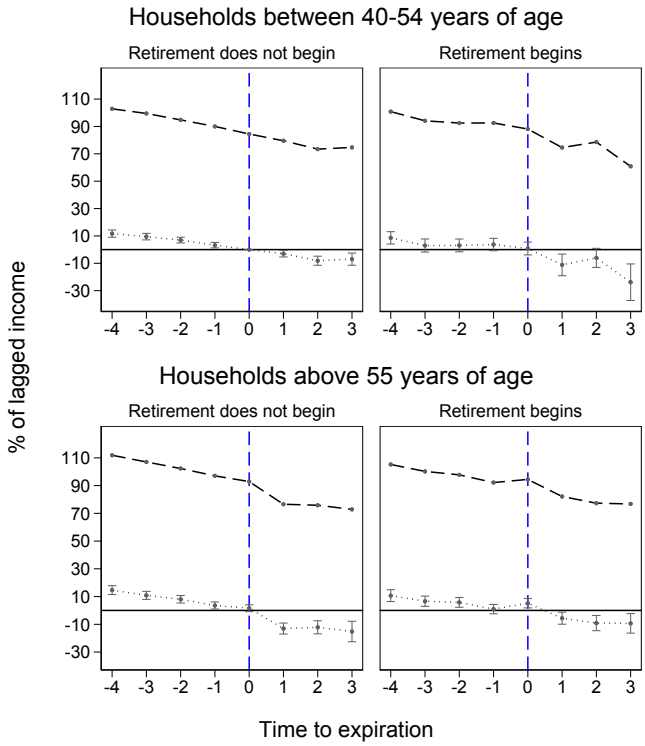


Figure IA.9: Consumption effect around expiration by retirement. The figure presents average values (dashed) and effects of time to expiration (TTE) (dotted) for consumption. Consumption is measured proportional to lagged income. It also includes the 95% confidence interval for effects of TTE. Results are plotted across age groups and to whether an individual in the household retires during the interest-only (IO) period. Age groups correspond to borrowers' age in the mortgage origination year, and differentiate between households between 40-54 years of age (row 1) and above 55 (row 2). Households included in the first column do not retire during the IO period, whereas those in the second column retires during the IO period. The estimation is based on the event study, stated in Eq. (2). To account for differences in age and retirement, dummy variables for age groups and whether an individual in the household retires during the IO period are included in the regression - both separately and interacted with TTE. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

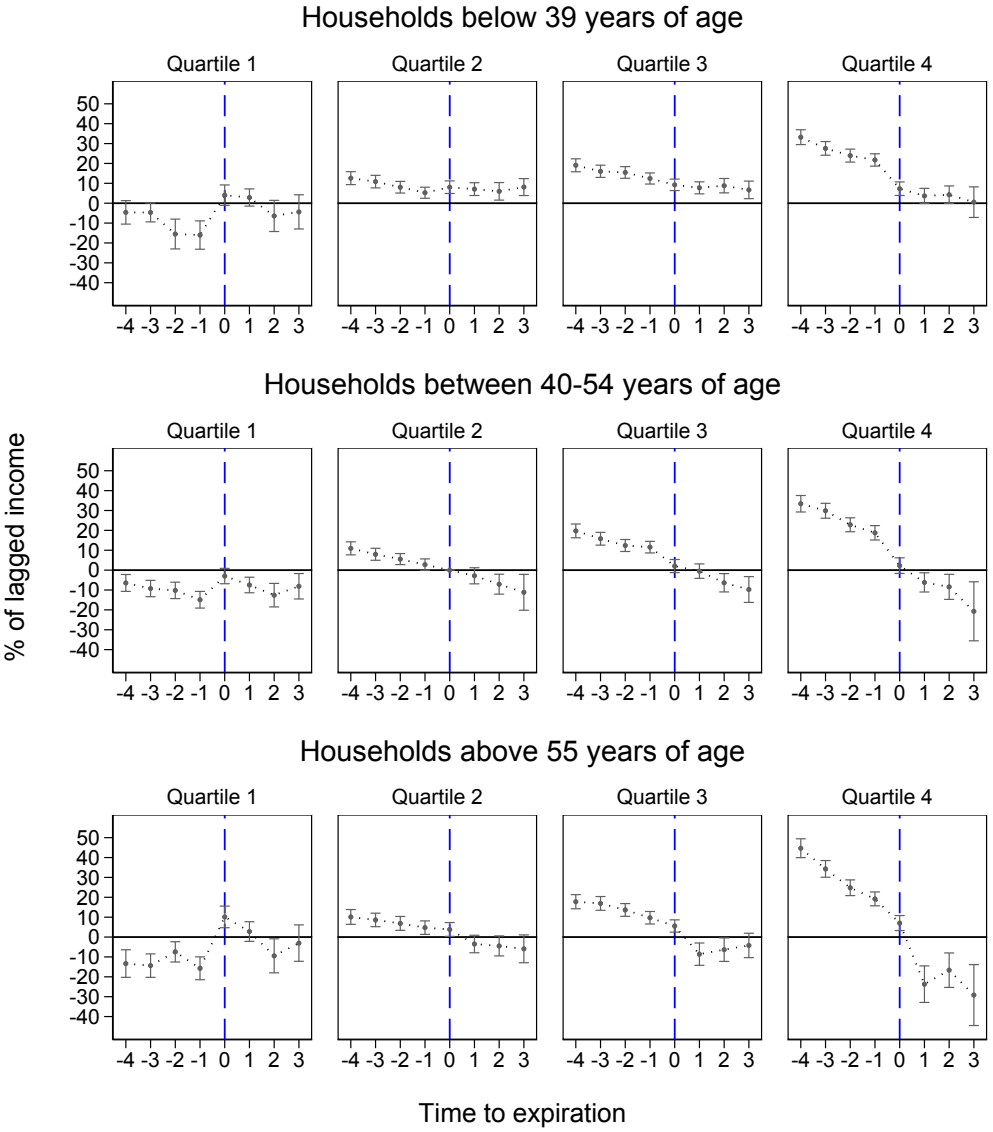


Figure IA.10: Consumption effect around expiration by age groups and quartiles of CTI. The figure presents effects of time to expiration (*TTE*) for consumption, measured proportional to lagged income. It also includes the 95% confidence interval. Results are plotted across age groups and across quartiles of average consumption to lagged income (CTI) during the interest-only (IO) period. The estimation is based on the event study, stated in Eq. (2). To account for differences in age and avg. consumption during the IO period, dummy variables for age groups and quartiles of average CTI during the IO period are included in the regression - both separately and interacted with *TTE*. Age groups differentiate between households below 39 years of age at mortgage origination (first row), between 40-54 (second row), and above 55 (third row). The first column represents households within quartile 1, second column households within quartile 2, third column households within quartile 3, and fourth column households within quartile 4. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

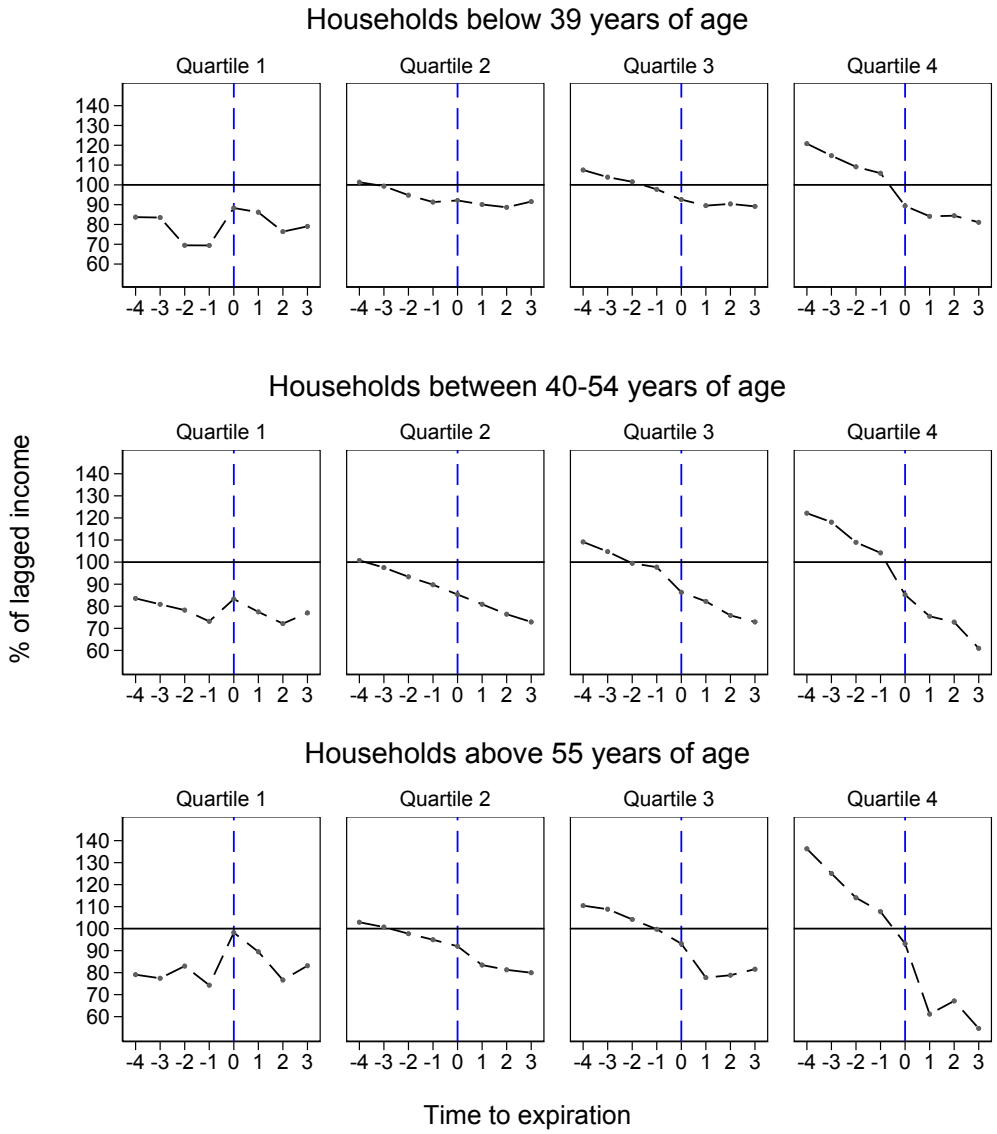


Figure IA.11: Average consumption around expiration by age groups and quartiles of CTI. The figure presents average values for consumption, measured proportional to lagged income. It also includes the 95% confidence interval. Results are plotted across age groups and across quartiles of average consumption to lagged income (CTI) during the interest-only (IO) period. The estimation is based on the event study, stated in Eq. (2). To account for differences in age and avg. consumption during the IO period, dummy variables for age groups and quartiles of average CTI during the IO period are included - both separately and interacted with *TTE*. Age groups differentiate between households below 39 years of age at mortgage origination (first row), between 40-54 (second row), and above 55 (third row). The first column represents households within quartile 1, second column households within quartile 2, third column households within quartile 3, and fourth column households within quartile 4. Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, and year fixed effect. The figure includes borrowers with IO mortgages originated between 2003 and 2008, which have kept the IO mortgage throughout the IO period and start amortization.

	IO period: 6	IO period: 7	IO period: 8	IO period: 10
Average CTI during IO period	0.033***	0.033***	0.052***	-0.009
	(0.008)	(0.010)	(0.010)	(0.009)
No kids during/No kids after	0.029***	0.028***	0.028***	-0.019**
	(0.010)	(0.011)	(0.011)	(0.009)
No kids during/kids after	0.077***	0.084***	0.071**	0.032
	(0.026)	(0.029)	(0.031)	(0.044)
Kids during/No kids after	0.013	-0.006	-0.016	-0.013
	(0.012)	(0.012)	(0.012)	(0.009)
Retires during IO period	0.024**	0.055***	0.056***	0.041***
	(0.010)	(0.010)	(0.009)	(0.008)
Unemployed during IO period	-0.034***	-0.021*	-0.023**	-0.012
	(0.011)	(0.011)	(0.011)	(0.008)
Loan to value (%)	0.000*	-0.000	-0.001***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Loan to value above 80%	-0.029***	-0.046***	-0.066***	-0.010
	(0.011)	(0.012)	(0.012)	(0.010)
Adjustable rate mortgage	-0.319***	-0.239***	-0.086***	-0.134***
	(0.007)	(0.008)	(0.008)	(0.008)
Zealand	-0.116***	-0.152***	-0.158***	-0.099***
	(0.009)	(0.010)	(0.009)	(0.008)
Southern Denmark	-0.070***	-0.095***	-0.149***	-0.119***
	(0.009)	(0.009)	(0.009)	(0.008)
Central Jutland	-0.008	-0.036***	-0.068***	-0.083***
	(0.009)	(0.010)	(0.009)	(0.009)
Northern Jutland	0.018	-0.049***	-0.079***	-0.119***
	(0.012)	(0.013)	(0.012)	(0.010)
Income growth over 3 year	-0.037	-0.118**	-0.324***	-0.077*
	(0.047)	(0.051)	(0.051)	(0.042)
Stock market participation	0.037***	0.044***	0.038***	0.008
	(0.008)	(0.008)	(0.008)	(0.007)
Risky Asset Share	0.037**	0.016	0.067***	0.047***
	(0.017)	(0.018)	(0.017)	(0.013)
Observations	20,540	19,568	21,994	14,360
Pseudo R-squared	0.238	0.178	0.142	0.203

Standard errors in parentheses

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table IA.1: Probit of mortgage choices for (a) Refinance to an IO mortgage. The table presents average partial effects of probit estimation on the mortgage choice at the end of the interest-only (IO) period, as stated in Eq. (1). The dependent variable is a dummy variable that takes a value of 1 for IO borrowers that refinance to an IO mortgage, and a value of 0 for IO borrowers that start amortization after 10 years. We run the probit estimation separately for each length of IO period (6, 7, 8, and 10 years). To ensure comparable controls, mortgage (and household) specific controls are measured one (and two) years prior to the base year, i.e. the year corresponding to the IO period where refinancing happens. Other controls included in the selection, but not reported, are origination year, age-group dummies, number of adult residents, dummies for kids living at home (in IO period and/or after), male, single, income, and bank holdings. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008.

	IO period: 6	IO period: 7	IO period: 8	IO period: 10
Average CTI during IO period	-0.015*	-0.029***	0.015	-0.001
	(0.008)	(0.010)	(0.011)	(0.010)
No kids during/No kids after	0.021**	0.009	0.001	-0.005
	(0.009)	(0.010)	(0.011)	(0.009)
No kids during/kids after	0.091***	0.038	0.011	0.045
	(0.024)	(0.027)	(0.029)	(0.044)
Kids during/No kids after	0.036***	0.021*	-0.006	0.000
	(0.011)	(0.011)	(0.011)	(0.009)
Retires during IO period	0.063***	0.050***	0.051***	0.029***
	(0.014)	(0.013)	(0.013)	(0.010)
Unemployed during IO period	-0.025**	-0.048***	-0.047***	-0.011
	(0.011)	(0.010)	(0.011)	(0.008)
Loan to value (%)	0.001***	0.001***	0.002***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Loan to value above 80%	-0.027***	-0.008	-0.029***	-0.010
	(0.010)	(0.010)	(0.011)	(0.009)
Adjustable rate mortgage	-0.434***	-0.386***	-0.340***	-0.296***
	(0.008)	(0.009)	(0.008)	(0.010)
Zealand	-0.055***	-0.059***	-0.056***	-0.057***
	(0.009)	(0.009)	(0.010)	(0.008)
Southern Denmark	-0.043***	-0.053***	-0.077***	-0.077***
	(0.009)	(0.009)	(0.010)	(0.008)
Central Jutland	-0.029***	-0.022**	-0.026**	-0.063***
	(0.009)	(0.010)	(0.010)	(0.009)
Northern Jutland	-0.008	-0.030**	-0.018	-0.074***
	(0.013)	(0.013)	(0.014)	(0.011)
Income growth over 3 year	0.161***	0.030	-0.033	0.140***
	(0.048)	(0.051)	(0.055)	(0.043)
Stock market participation	0.031***	0.026***	0.028***	0.006
	(0.008)	(0.008)	(0.009)	(0.008)
Risky Asset Share	-0.023	-0.031	-0.009	0.006
	(0.018)	(0.019)	(0.019)	(0.016)
Observations	15,078	16,073	18,384	14,510
Pseudo R-squared	0.277	0.197	0.112	0.171

Standard errors in parentheses

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table IA.2: Probit of mortgage choices for (b) Refinance to a repayment mortgage. The table presents average partial effects of probit estimation on the mortgage choice at the end of the interest-only (IO) period, as stated in Eq. (1). The dependent variable is a dummy variable that takes a value of 1 for IO borrowers that refinance to a repayment mortgage, and a value of 0 for IO borrowers that start amortization after 10 years. We run the probit estimation separately for each length of IO period (6, 7, 8, and 10 years). To ensure comparable controls, mortgage (and household) specific controls are measured one (and two) years prior to the base year, i.e. the year corresponding to the IO period where refinancing happens. Other controls included in the selection, but not reported, are origination year, age-group dummies, number of adult residents, dummies for kids living at home (in IO period and/or after), male, single, income, and bank holdings. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008.

	IO period: 6	IO period: 7	IO period: 8
Average CTI during IO period	-0.018***	-0.008	-0.021***
	(0.006)	(0.006)	(0.008)
No kids during/No kids after	-0.006	0.004	0.003
	(0.007)	(0.007)	(0.008)
No kids during/kids after	0.007	-0.006	-0.020
	(0.019)	(0.018)	(0.021)
Kids during/No kids after	0.005	-0.007	0.015*
	(0.008)	(0.007)	(0.009)
Retires during IO period	0.006	-0.002	-0.011
	(0.009)	(0.008)	(0.007)
Unemployed during IO period	0.003	0.007	-0.011
	(0.008)	(0.008)	(0.008)
Loan to value (%)	-0.000	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)
Loan to value above 80%	-0.005	0.005	-0.017**
	(0.007)	(0.007)	(0.008)
Adjustable rate mortgage	0.022***	0.028***	0.062***
	(0.005)	(0.005)	(0.005)
Zealand	-0.028***	-0.019***	0.006
	(0.007)	(0.007)	(0.008)
Southern Denmark	-0.035***	-0.039***	-0.016**
	(0.007)	(0.006)	(0.007)
Central Jutland	-0.030***	-0.027***	-0.007
	(0.007)	(0.007)	(0.008)
Northern Jutland	-0.044***	-0.029***	0.011
	(0.008)	(0.009)	(0.010)
Income growth over 3 year	0.076**	0.044	0.037
	(0.033)	(0.033)	(0.041)
Stock market participation	0.002	0.009	0.016**
	(0.006)	(0.006)	(0.007)
Risky Asset Share	0.009	0.000	0.008
	(0.012)	(0.012)	(0.013)
Observations	12,124	12,593	13,617
Pseudo R-squared	0.066	0.054	0.087

Standard errors in parentheses

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table IA.3: Probit of mortgage choices for (c) Start amortization early. The table presents average partial effects of probit estimation on the mortgage choice at the end of the interest-only (IO) period, as stated in Eq. (1). The dependent variable is a dummy variable that takes a value of 1 for IO borrowers that start amortization early, and a value of 0 for IO borrowers that start amortization after 10 years. We run the probit estimation separately for each length of IO period (6, 7, 8, and 10 years). To ensure comparable controls, mortgage (and household) specific controls are measured one (and two) years prior to the base year, i.e. the year corresponding to the IO period where early amortization happens. Other controls included in the selection, but not reported, are origination year, age-group dummies, number of adult residents, dummies for kids living at home (in IO period and/or after), male, single, income, and bank holdings. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008.

Mortgage payment	IO period: 6 years	IO period: 7 years	IO period: 8 years	IO period: 10 years
Expired	0.057***	0.056***	0.062***	0.082***
	(0.004)	(0.004)	(0.004)	(0.001)
Observations	5,864	5,642	9,391	75,239
R-squared	0.207	0.196	0.207	0.351
Adj. R-squared	0.204	0.192	0.205	0.351

Consumption	IO period: 6 years	IO period: 7 years	IO period: 8 years	IO period: 10 years
Expired	-0.031***	-0.037***	-0.016**	-0.035***
	(0.008)	(0.009)	(0.008)	(0.003)
Observations	5,864	5,642	9,391	75,239
R-squared	0.087	0.087	0.078	0.115
Adj. R-squared	0.083	0.083	0.076	0.115

Standard errors in parentheses

$*p < 0.10, **p < 0.05, ***p < 0.01$

Table IA.4: Average effect in amortization period. The table presents the average change in consumption and mortgage payments before and after the interest-only (IO) period ends. Each column presents average effect for IO periods of 6, 7, 8 and 10 years. The average effect is estimated for IO borrowers that start amortization after 6, 7, 8, and 10 years. The average effect is based on the event study, specified in Eq. (2), but with a dummy *(Expired)* indicating the four years before the IO period expires vs. four years after instead of time to end (TTE). The table also presents robust standard errors (clustered at the household level). Controls are measured at t-2 and include number of adult residents, a dummy for kids living at home, a dummy for gender, dummy variables for educational levels, debt-to-asset, and income. We also include a dummy for the mortgage interest rate type (ARM or FRM) measured at t-1, regional fixed effects, age-group dummies reflecting their age at origination of the IO mortgage, and year fixed effect. All variables are inflation-adjusted to represent 2020-prices. The table includes borrowers with IO mortgages originated between 2003 and 2008.

Chapter 3

Double Jeopardy: Households' consumption responses to shocks in stock *and* mortgage markets

Double Jeopardy: Households' consumption responses to shocks in stock *and* mortgage markets

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October 29, 2021

Abstract

Households adjust consumption downwards following negative shocks to their stock holdings. Households also lower consumption following exogenous increases in mortgage debt payments. But what is the impact of simultaneous adverse shocks in both markets, such as in the 2008 financial crisis? Using detailed Danish household data we find that the reduction in consumption doubles if households are highly exposed to both the stock and the mortgage market. We also find that the negative effects persist over time. It has a severe effect on consumption as households with a high-risk profile in the asset market also tend to have high exposure in the debt market. We discuss underlying reasons behind our results and their implications for macroprudential policies.

Keywords: Mortgage choice; micro data; risk attitudes; stock market participation; consumption effects; financial crisis.

JEL subject codes: G11

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1 Introduction

During economic and financial crises, stock markets typically fall, credit-spreads widen, and yields on risky loans, including mortgage loans, rise, even when central banks lower policy rates. As an example, during the peak of the financial crisis, from September 18 to October 30, 2008, the S&P 500 lost 20% of its value and the 5/1-Year Adjustable Rate Mortgage (ARM) yield increased by almost one percentage point (from 5.7% to 6.4%), even when the Fed lowered the Fed Funds Target Rate (from 2% to 1.5%).[1]

An event like the financial crisis in 2008 of course has an effect on the economic situation of households. How much it affects an individual household depends on its exposure to the affected markets. A higher investment in the stock market increases the household's exposure to stock market gains and losses. The same goes for a risky position in mortgage markets, such as an adjustable-rate mortgage (ARM), an interest-only loan, and/or higher mortgage payments relative to income. If households choosing risky positions in the mortgage market also tend to choose risky positions in the stock market, it magnifies the overall financial exposure of the household, thereby increasing the household's sensitivity to economic and financial shocks.

Prior literature tests the consumption effect of stock market changes, and find that consumption falls when stock markets fall, see, e.g. Dynan and Maki (2001), Case, Quigley, and Shiller (2005), Bostic, Gabriel, and Painter (2009), and Di Maggio, Kermani, and Majlesi (2020). A related branch of the literature investigates the consumption effect of mortgage rate changes, and find that consumption falls when mortgage rates increase, see, e.g. Agarwal, Amromin, Ben-David, Chomsisengphet, Piskorski, and Seru (2017) and Di Maggio, Kermani, Keys, Piskorski, Ramcharan, Seru, and Yao (2017). But what if the households' assets and liabilities are hit at the same time? Is the total effect on households' consumption the sum of the effect from the stock market on its own and the effect of an interest-rate change on its own, is there a diversification effect that softens the impact, or is the total effect even magnified when households are hit by shocks to both markets?

This paper investigates the effect on household consumption from negative shocks to the mortgage and the stock markets during the financial crisis in 2008 using detailed individual-investor data from Denmark. We find that the negative consumption reduction for households highly exposed to both the stock market and the mortgage market are approximately 100% larger, compared to households only exposed to one market. To measure this, we exploit cross-sectional variation across households' risk attitudes towards mortgage and stock markets. We find that households who are highly exposed to either the mortgage or the stock market, but not both, cut consumption by an additional 10% in 2008, compared to households having a low exposure to both the stock and mortgage markets. Households who are highly exposed to both the stock and the mortgage markets cut consumption by approximately 20%, i.e. they face a consumption reduction 100% larger than households only exposed to one market.

[1] Data source: St. Louis Fed FRED Database.

We use very detailed individual-investor panel data from 2007 to 2011. We combine mortgage data provided by one of the largest mortgage banks in Denmark with Danish high-quality register-based data made available by Statistics Denmark. We have information on households' choice of mortgage and the market value of their total stock holdings. We also have a host of socioeconomic data and property data. We calculate proxies for the riskiness of the household's stock-market and mortgage-market positions. To determine the riskiness of the mortgage for each household, we examine their mortgage payment-to-income ratio, the ratio of debt to assets, and the mortgage type. As a measure of the riskiness of the asset position, we use the risky asset share, i.e. the sum of stocks and mutual funds divided by the total sum of liquid assets.

The time span of our data allows us to test the consumption implications of households' risk attitudes towards assets and liabilities during the financial crisis in 2008. In Denmark, like in other countries (cf. first paragraph in this Introduction), both the mortgage and the stock markets were negatively affected by the financial crisis, i.e. the stock market fell and mortgage rates increased. We study stock market participants with a mortgage in 2007 to capture pre-crisis market exposure. We follow each household during the negative shock in 2008, and in the period thereafter, until 2011.

We first test whether households choosing a risky position in the stock market tend to choose a risky position in the mortgage market, too, and vice-versa. For all proxies of risk attitude towards liabilities, we find a positive correlation; households with a high-risk profile with respect to the mortgage market tend to hold a high share of risky assets. This is important as the additional effect of taking risky positions in both markets may exacerbate the negative impact on household consumption when a negative economic shock simultaneously affects both markets.

Second, we exploit the financial crisis to test the effect of risk attitudes with respect to stocks and mortgages on consumption using a Triple Difference approach. We show that households choosing a risky position in the mortgage market and a high exposure to the stock market are hurt more by a simultaneous negative shock than households highly exposed to one market only. We find that households highly exposed to interest rate movements reduce consumption in 2008 by app. 11% more than households who are little exposed to the mortgage market. Similarly, households highly exposed to the stock market reduce consumption in 2008 by app. 10.0% more than households who are little exposed to the stock market. Furthermore, and as our main result, we find that households who are highly exposed to both stocks and mortgages reduce their consumption in 2008 by 20.5%, compared to households who have low exposure to both the mortgage and the stock markets. These results imply that households highly exposed to both markets are hurt by the sum of the consumption effects of the two markets as we find no lenient nor strengthening effect of being highly exposed to both markets. In total, a household highly exposed to both markets is hurt 100% more than a household only exposed to one market.

We also examine whether the shock in 2008 has persistent effects. We find that the consumption effect of the negative economic shock in 2008 persists for several years, however with diminishing

effect. The persistency is driven by the stock market. Households highly exposed to the stock market tend to stop investing in risky assets during the years following the financial crisis. This exit-effect is largest for households who also choose a high-risk mortgage, especially for households with relatively few liquid assets before the crisis. We argue that this reflects a learning pattern or a need for liquidity, i.e. households sell risky assets to reduce overall risk or to release liquid assets to cover mortgage payments. These results are consistent with related findings that show that investors who have had a bad experience with the stock market subsequently participate less in the stock market (see e.g Andersen, Hanspal, and Nielsen (2019), Zhou (2020), and Malmendier and Nagel (2011)). Our findings indicate, though, that stock-selling in our setting is rather driven by a need for liquidity than a way to cut losses.

Our results have implications for financial stability and macroprudential policy, as well as for household finances. Some types of macroprudential policy aim at reducing households' mortgage borrowing, with potential costs on output (Richter, Schularick, and Shim (2019)). Our paper highlights that households who are highly indebted tend to take higher risks in stock markets, too, resulting in even more severe consumption reductions in times of crises. In this sense, our paper provides some support for reducing excessive leverage at the household level.

Our study combines two areas of the household finance literature, i.e., papers investigating how interest/mortgage rate changes affect household consumption (Agarwal et al. (2017) and Di Maggio et al. (2017)) and papers on the consumption effect of stock markets changes (Dynan and Maki (2001), Case et al. (2005), Bostic et al. (2009), and Di Maggio et al. (2020)). For example on the asset side, using Swedish household-level data from 1999-2007, Di Maggio et al. (2020) find that an unrealized capital gain of one-dollar increases household consumption by 23 cents for the bottom 50% of the wealth distribution. For the top 30th percentile of the wealth distribution, it is only 3 cents. Bostic et al. (2009), Case et al. (2005), and Dynan and Maki (2001) investigate how housing wealth and financial wealth affect consumption. They estimate the consumption effect of financial wealth to 0% to 15%. On the debt side, Agarwal et al. (2017) exploit the effect of the 2009 Home Affordable Modification Program (HAMP) that provided financial incentives for intermediaries to renegotiate mortgages. They show that a reduction in mortgage rates increases consumption (durable auto consumption). For US households with ARMs originated between 2005-2007, Di Maggio et al. (2017) show that a decline in mortgage payments caused by a fall in interest rates increases spending on car purchases by 25 to 35 percent, on average. All of these papers show an effect of a change in the stock market or a change in debt market on consumption. We show the importance of considering both markets in times of crises, as the tendency to choose a high-risk level in the stock and mortgage markets correlates positively. This positive correlation increases the overall risk of the household. We find that it amplifies the total consumption reduction of a negative economic shock. As both the stock and the mortgage market is hit by a bad economic shock in 2008 simultaneously, household consumption is not only reduced by app. 11% or 10%, but almost twice as much (-20.5%), for households highly exposed to both markets.

Our paper is also closely related to literature that investigates household finances sur-rounding the financial crisis. Mian and Sufi (2010), Mian, Rao, and Sufi (2013), Dynan (2012), Bunn and Rostom (2014), Baker (2015), and Andersen, Duus, and Jensen (2016) find a negative relation between debt levels prior to the crisis and consumption growth during the financial crisis. Andersen et al. (2016) find that the pre-crisis debt level has no effect on consumption when they control for the change in debt in the year prior to the crisis. They argue that a "spending-normalization pattern" drives the correlation, i.e. households have used debt to finance temporarily increased consumption prior to the crisis and then reduce consumption to its normal level during the crisis. Jensen and Johannesen (2017) show that the reduction in household consumption during the financial crisis is driven by a credit supply shock of distressed banks. We contribute to this literature by showing what happens if households are exposed to both stock and mortgage markets.

Another area of household finance also relates to our study. Kaustia and Knüpfer (2008), Malmendier and Nagel (2011), Bucher-Koenen and Ziegelmeyer (2014), and Andersen et al. (2019) show that personal experiences shape investors' behaviour (in the US, UK, and Denmark). Investors are more likely to sell a risky stock that just lost value. By selling a risky asset that has performed poorly, households realize the loss and make it permanent. Consequently, they reduce wealth permanently, which potentially decreases current or future consumption. These papers study one market. Considering both the asset and liability side of households' balance sheet is important in times of crises, our paper shows.

Lastly, our study is connected to papers that examine the correlation between the markets for assets and liabilities. Chetty, Sándor, and Szeidl (2017) show that an exogenous increase in mortgage debt induces a significant reduction in the fraction of wealth allocated to stocks in the household's portfolio, whereas an exogenous increase in home equity raises stock ownership. Becker and Shabani (2010) find that households with a mortgage loan are 10% less likely to own stocks and 37% less likely to own bonds compared to similar households with no mortgage loan. While both of these papers show the importance of housing and mortgages on the household's stock market participation, neither focuses on the riskiness of their holdings. We find that investors holding both stocks and mortgages tend to take high risk (or low risk) on both markets, which underlines the importance of considering both markets when evaluating consumption impacts of economic shocks.

The remainder of the paper is organized as follows. Section 2 provides a short introduction to the Danish mortgage and stock market participation, describes our data set, and presents summary statistics. Section 3 estimates the correlation between risky holdings in stock and mortgage markets. Section 4 documents how much a given household is hurt by taking more risk in both markets when a bad shock occurs to both markets simultaneously. Section 5 provides evidence for the persistency of the consumption effect and the aftershock behaviour of investors and mortgage holders. Finally, Section 6 concludes.

2 Data

To examine the implications of households' risk exposure towards assets and liabilities, we examine the stock market as the main market for households' liquid assets, and the mortgage market for liabilities. Therefore, the data used in this paper consists of households participating on both the stock and mortgage market, i.e. homeowners with a mortgage and stock holdings. Our aim is to examine the consequences of the negative economic shock resulting from the eruption of the financial crisis in late 2008. To reflect pre-crisis conditions, our base condition is end-of-year values in 2007. We then follow the households during 2008 and in a three-year period after the negative shock (until 2011).

To access all the necessary information, we combine several panel data sets. One of the largest mortgage banks in Denmark provides the mortgage data. It includes detailed information on the mortgages, e.g. mortgage type, principal, outstanding debt, interest rate, etc., and includes around 776,000 mortgages issued from 2007 to 2011.[2]

The household's economic data, including the market valuation of stock holdings, come from register-based data made available by Statistics Denmark. Statistics Denmark also provides socio-economic data and property data, such as public property valuation, family relations, age, etc. We combine the mortgage data and the register-based data using the anonymized identification number of the individual and the property. Further, we use information on family relations to aggregate all individual data to the household level.

2.1 Mortgage and stock market participation

Before going into details on our data, we provide a short overview of the Danish mortgage system and Danes' stock market participation.

In Denmark, the main providers of residential mortgage loans are specialized mortgage banks, acting as intermediaries between households and investors. The mortgage banks back up mortgages by issuing a series of identical covered bonds on Nasdaq Nordic Exchange. Consequently, the interest rate on the mortgage matches the coupon rate of the covered bonds. Borrowers are allowed to borrow up to 80% of the property value. Based on data of the entire Danish population from Denmark Statistics, a bit more than half of Danish households are homeowners at the end of 2007. 77% of the Danish homeowners have a mortgage, and the average loan-to-value is 57% for homeowners with a mortgage (44% for all homeowners).[3]

The mortgage banks offer fixed rate mortgages and adjustable rate mortgages with a maturity up to 30 years. Adjustable rate mortgages are offered with various rate-reset frequencies from every

[2] We focus on mortgages issued on residential property as we focus on household finance. Mortgages issued before 1970 are excluded, because of a major reform of mortgage regulation in that year, which reduced the maximum loan-to-value ratio and the maximum maturity. There is a random sub-sample of 18% in 2007 of which the interest rate type is incomplete.

[3] Loan-to-value is measured as the total mortgage debt as a percentage of the total public property value of all properties owned by the household.

quarter to every tenth year. Fixed rate mortgages offer the borrower a fixed rate until maturity. Regardless of the types of mortgage interest rates, mortgages are offered with or without an option to pay interest payments only (Interest-Rate Only loans) for a maximum period of ten years. At the end of 2007, 55% of the face value of the outstanding mortgage-backed bonds are with adjustable rate, and 45% include an interest-only option.

In our data, 34% of Danish households hold stocks at the end of 2007. The average stockholding equals DKK 265,000 corresponding to app. USD 42,000. Relative to the US and Sweden, the stock market participation rate in Denmark is low, whereas it is relatively high compared to other European countries, such as Austria, Italy, and Spain (Guiso and Sodini (2013)). Existing literature (Florentsen, Nielsson, Raahauge, and Rangvid (2020) and Andersen et al. (2019)) finds that Danish stockholders are generally wealthier, older, have higher income, higher education and are more likely to be male and married than nonparticipants.

[Figure 1 about here.]

Like the rest of the world, the Danish mortgage and stock markets were hit hard by the financial crisis that erupted late 2008. Figure 1a presents the daily closing price of the Danish stock index, OMX C20, and for comparison the daily closing price of S&P500.[4] Figure 1b displays the weekly average of Danish mortgage rates in percent. It follows, that the Danish stock market fell dramatically in late 2008. At the same time, the short rate on the Danish mortgage market increased by approximately 50% from around 4% to 6% as seen in Figure 1b. That is, both the stock and the mortgage market experienced a large negative shock during the financial crisis in 2008. Depending on a given household's risk exposure in the two markets, these shocks should have an effect on the household's consumption. The interesting question is then if the consumption of households highly exposed in both markets are hit more or if there is some diversification effect that softens the impact compared to households only highly exposed in one of the two markets? This is what we want to examine in this paper.

2.2 Summary statistics

Our aim is to investigate the effect on household consumption from simultaneously negative shocks to the mortgage and the stock market. Hence, our data include a panel of homeowners with a mortgage and a stock position in 2007. In total, we have 83,083 households and 367,921 observations from 2007 to 2011.

Table 1 presents the summary statistics of the year in which we fix our buckets, i.e. 2007. We track the households through the 2007 to 2011 period, so for completeness we also include statistics for the whole period. For 2007 to 2011, we report average annual statistics.

[Table 1 about here.]

[4] OMX C20 is the stock index for the twenty most traded Danish stocks on NASDAQ.

Like Brunnermeier and Nagel (2008) and Calvet and Sodini (2014), we measure the household's willingness to take on asset risk as their liquid risky asset share, i.e. the sum of stocks and mutual funds divided by the total sum of liquid assets. We define liquid assets as the sum of cash, stock, and bond holdings. From Table 1 it follows that in 2007 31.7% of all liquid assets are stocks and mutual funds, whereas the risky asset share equals 23% for the whole period. The difference may reflect a relatively high willingness to take risk on the asset market or a relatively high market valuation of stocks in 2007. It also follows that 94% of our sample are participating in the stock market over the full period from 2007-2011. By construction, the stock market participation equals 100% in 2007.

The debt-to-asset ratio, mortgage payment-to-income, and the mortgage type are all indicators of the risk of the liabilities. An increase in the debt-to-asset and mortgage payment-to-income ratios increases the household's exposure to changes in the interest rate, which reflects a riskier position on the mortgage market. For the mortgage types, adjustable rate mortgages are more exposed to changes in the interest rate compared to fixed rate mortgages. Interest-only mortgages involve more risk compared to repayment mortgages because interest-only mortgages postpone the repayment, forcing the household to repay the mortgage over a shorter period. Table 1 shows the summary statistics of these indicators.

It follows from Table 1 that total debt is on average DKK 578,517 (USD 91,828) per adult in the household in 2007.[5] This corresponds to a debt-to-asset ratio of 53.0%.[6] The majority of the debt is mortgage debt, which on average equals DKK 446,335 (USD 70,846) per adult in the household. The loan value-to-income ratio shows that the average household borrows a bit more than 3 times their annual income, and that the annual mortgage payment equals 19.5% of their income. Household income is measured as the disposable income of the household, which is defined as total income (labor income, social welfare benefits, unemployment benefits, child benefits, pension payouts, capital income, and inheritance) less interest payments and tax payments. From Table 1 it follows that the average household has an annual disposable income of DKK 155,448 (USD 24,674) per adult. Regarding the mortgage type we see that 28.5% of the households hold an interest-only mortgage and 43.8% an adjustable rate mortgage in 2007.[7] If we compare with the full period from 2007-2011 we see that the total value of debt increases over the sample period. The same is the case for the use of interest-only mortgages and adjustable rate mortgages. Falling interest rates (Figure 1b) and increasing use of adjustable rate mortgages explain the lower average mortgage payment-to-income ratios for 2007 to 2011 compared to 2007. Lastly, income is a bit higher for the whole sample period compared to 2007, which is expected as income typically increases over time.

[5] Loan amounts, debt, and income are measured as an average per adult in the household to make the households comparable.

[6] The household's assets equal the sum of bank deposits, stock holding, bond holdings, and the public property value of all properties owned by the household.

[7] If a household has several mortgages, the mortgage-specific variables are those relating to the largest mortgage, i.e. the mortgage with the highest loan amount.

In our empirical test we control for different household-specific variables that prior literature has found to be relevant for households' decisions regarding debt and investments. We include household age (average age of mortgage-borrowers), relationship status, and gender. To account for financial sophistication, we include the highest educational level in the household. Level 1 represents primary school or less, level 2 secondary school or vocational education, and level 3 is short-, medium-, long-term higher education, PhD or researcher education. Finally, we control for geographical differences. We use the five administrative regions of Denmark (Copenhagen, Zealand, Southern Denmark, Central Jutland, and Northern Jutland) of which the property is located to represent the geographical dimension. Comparing the household-specific variables in 2007 with the whole period, we see almost no difference. This indicates that the household types in the sample do not change much over the years and the outflow of customers are random with respect to household types.

3 Correlation between risky holdings in stock and mortgage markets

The investor's risk allocation towards stocks and mortgages and the correlation between the two are important factors influencing the total financial risk of the household. For instance, a household who has financed its house with a risky mortgage and at the same time has a high risky asset share is exposed to negative economic shocks from two markets and hence more sensitive to economic shocks in general, compared to a household only being exposed to one market.

To investigate the correlation between household i's risk allocation towards stocks and mortgages, we use the OLS specification:

$$\begin{aligned} RAS_i =& \alpha_0 + \beta_1 DTA_i + \beta_2 MTI_i + \beta_3 D_i^{\text{ARM}} + \beta_4 D_i^{\text{IO}} + \beta_5 D_i^{\text{ARM}} D_i^{\text{IO}} \\ &+ \xi' C_i + u_i. \end{aligned} \tag{1}$$

Here, RAS is the risky asset share, DTA is the debt-to-asset ratio, and MTI is the mortgage payment-to-income ratio. Debt-to-asset and mortgage payment-to-income are scaled by their annual standard deviation. D^{ARM} (D^{IO}) is a dummy variable equal to one if the mortgage is an adjustable rate mortgage (interest-only mortgage). To test if there is an additional effect of having an interest-only mortgage with an adjustable rate, i.e. the most sensitive loan, we include the interaction $D^{\text{ARM}} D^{\text{IO}}$ in our regression. C is a vector of control variables defined in Table 1, i.e. age, income, number of residents, relationship status, gender, educational level, as well as regional dummies. We run the OLS regression for 2007 to investigate the correlation between risk attitude towards assets and liabilities just prior to the financial crisis.[8]

[Table 2 about here.]

Table 2 presents the results from the regression. All β-coefficients are significant and positive

[8] For robustness, we repeat the analysis year-by-year from 2007-2011 for stockholders with a mortgage in the given year. We find the same overall pattern over the years. The results are available upon request.

except β_5 which is insignificant. Hence, we see a clear positive relation between the risk allocation with respect to the stock market and the risk allocation towards the mortgage market. However, we do not find any additional effect of having an interest-only mortgage with an adjustable rate.

In more detail, holding everything else fixed, increasing debt-to-asset by one annual standard deviation increases risky-asset-share by 2.6 percentage points. Compared to an average risky-asset-share ratio of 0.32 in 2007, the economic effect is relatively large as it corresponds to an increase in risky-asset-share of 8.20%. For mortgage payment-to-income, an increase of one annual standard deviation increases risky-asset-share by 1.2 percentage points, corresponding to a 3.8%-increase.

Additionally, we find that the mortgage choice is positively related to risky-asset-share. Comparing two similar households who only differ with respect to their mortgage choice, we find that a household with a repayment adjustable-rate mortgage (an interest-only fixed-rate mortgage) has a 3.0 (0.9) percentage point higher risky-asset-share on average, compared to the households having a repayment fixed-rate mortgage. The economic effect is in particular large for the choice of an adjustable rate mortgage. Compared to the average risky-asset-share ratio of 31.7%, an increase of 3-percentage points corresponds to an increase in the risky-asset-share ratio of 9.5%, whereas the economic effect for the choice of an interest-only mortgage equals 2.8%.

Chetty et al. (2017) show that an exogenous increase in mortgage debt induces a significant reduction in the fraction of wealth allocated to stocks in households' financial portfolios. Another related paper, Becker and Shabani (2010), finds that households with a mortgage loan are 10% less likely to own stocks and 37% less likely to own bonds compared to similar households with no mortgage loan. Whereas both of these papers show the importance of housing and mortgage on the household's stock market participation, they differ from our results as neither of them study the riskiness of the mortgage and how it relates to the degree of stock market exposure for households participating on the stock market. We contribute by showing that a positive correlation between the risk attitude towards assets and liabilities exists.

The positive correlation between risk taking on the asset and liability side of the household's balance sheet (i.e. investors with a high exposure to risky assets tend to take a risky mortgage loan, such as an adjustable rate mortgage and/or an interest-only loan) magnifies the risk of the financial position of the household. This additional risk amplifies the financial sensitivity of the household to economic shocks. This is important for the welfare of the household as the additional risk of taking risky positions in both markets may hurt the consumption of the household to a greater extend when negative economic shocks occur. This is what we examine in the next section.

4 Consumption effect of risk allocation

To investigate the consumption impact of risky positions in both stock and mortgage markets, we exploit the volatile economic situation around the eruption of the financial crisis in 2008, where both markets are hit by a negative shock (Figure 1). We use the fact that both shocks are of the same direction (i.e. negative shocks) to evaluate the consumption implications for households in

bad times. We focus on those households affected by changes in mortgage rates and accordingly restrict our sample to households with adjustable-rate mortgages in 2007 and 2008 that resets the interest at least once a year. Furthermore, we only include households holding stocks in both 2007 and 2008. This brings us down to a sample of 28,079 households.

Consumption is imputed from the income and wealth data supplied by Statistics Denmark, as done by Leth-Petersen (2010) and others.[9] Let c_t denote the consumption in year t, y_t the disposable income, A_t, the value of the household's liquid assets (bank deposits including the balance of the private pension schemes), M_t mortgage debt, and D_t bank debt and other debt at the end of year t. Based on the household budget constraint, total consumption is then imputed as

$$c_t = y_t - \Delta A_t + \Delta M_t + \Delta D_t, \tag{2}$$

where $\Delta A_t = A_t - A_{t-1}$ is the increase in liquid assets plus private pension contributions in year t, $\Delta M_t = M_t - M_{t-1}$ is the increase in mortgage debt, and ΔD_t the increase in bank debt and other debt in year t.[10] Note, the liquid assets, A_t, do not include stock and bond holdings. This is to avoid excessive levels of consumption in years where the markets are very volatile, such as the financial crisis. We cannot distinguish between changes in asset values due to active investment decisions of the household and changes due to unrealized gains and losses caused by market movements. We find that consumption imputed without stock and bond holdings align well with survey-based consumption data, whereas imputed consumption calculated including stock and bond holdings are excessively volatile (results are available upon request). We disregard consumption in years where the household buys or sells real estate. The reason for this is that the actual value of the house is unobservable between transactions. Consequently, in years where the household sells or buys real estate, imputed consumption is only affected from the debt side, and can severely misrepresent actual consumption. Finally, we exclude households with self-employed individuals in order to avoid misestimating consumption caused by unstable income-tax conditions and the difficulties in measuring the value of their business.

As we want to investigate the consumption effect of risk attitudes towards both the stock and mortgage market, we need to differentiate between households' choice of risk exposure towards each market. We distinguish between four risk profiles:

1. high risk allocations on both markets

2. high risk allocation towards the stock market and low towards the mortgage market

[9] Browning and Leth-Petersen (2003) investigate the quality of the imputed consumption measure by comparing self-reported total expenditure from a Danish Expenditure Survey to the imputed consumption measure from administrative data. They conclude that the imputation is of good quality. Koijen, van Nieuwerburgh, and Vestman (2015) argue for the use of imputed register-based consumption to avoid reporting errors in consumption survey data. Their recommendation is based on their findings of substantial reporting errors in Swedish consumption survey data.

[10] Disposable income includes private pension contributions (and excludes mandatory occupational pension contributions). Pension contributions are considered as an increase in liquid assets and are thus included in ΔA_t.

3. low risk allocation towards the stock market and high towards the mortgage market

4. low risk allocations on both markets

A household with a low mortgage payment-to-income ratio (risky-asset-share) reflects a household with low exposure to economic shocks in the mortgage (stock) market. We set the annual threshold for the low and the high level of exposure to a market at the 25th and 75th percentile, respectively. This means that households who use less than 25% of their disposable income on mortgage payments (i.e. households for whom the mortgage payment-to-income ratio is below 25%) are considered as households with low risk allocation to the mortgage market. Similarly, households who use more than 75% of their disposable income on mortgage payments are households with high risk allocation to the mortgage market. Households with values of mortgage payment-to-income above the 25th percentile and below the 75th percentile are not used. We treat households' choice of risky-asset share in the same manner, i.e. households with a risky-asset share lower than 25% are considered low asset risk households, and those with more than 75% in risky assets are high asset risk households.

As in section 3, exposure towards the stock market is measured by the risky-asset share. The exposure towards the mortgage market is measured by the mortgage payment-to-income ratio, which is one of the three measures used in section 3. The mortgage payment-to-income is the preferred risk measure of mortgage risk because of its close linkage to the interest rate of the mortgage. Shocks in the mortgage market, i.e. changes in the mortgage rate, will immediately affect the mortgage payment for households with an adjustable rate mortgage, and hence immediately affect the consumption of the household if the household is liquidity constrained. Naturally, we focus on households that are exposed to shocks in all years, i.e. we restrict the consumption analysis to only include households with an adjustable rate mortgage that resets the interest rate at least once a year.

[Table 3 about here.]

Table 3 presents summary statistics for the four risk profiles in 2007. Remember that we have sorted households on their choice of risky-asset-share and mortgage payment-to-income ratio. Hence, per construction, the risky-asset-share is much higher (79%) for households with a high exposure to the stock market, compared to those with low exposure (4%). Similarly, the mortgage payment-to-income ratio is 39% for households with a high exposure to the mortgage market, and only 9% for those with a low exposure. This shows that there is a large difference between households with high/low risk allocations in the mortgage and stock markets.

Higher debt increases mortgage payments (all else equal) whereas income decreases the mortgage payment-to-income ratio, so, as expected, we find in Table 3 that the debt level is relatively higher and income relatively lower for household with high mortgage payment-to-income ratios. Consistent with existing literature, we find a high spread in stock holdings among Danish stockholders (see e.g. Florentsen et al. (2020)) - the market value of stocks is much higher for the risk

profiles with high levels of risky-asset-share compared to those with a low level. Finally, it follows from Table 3 that consumption is higher for the risk profiles with high levels of risky-asset-share, which associates with wealthier households investing more.

[Table 4 about here.]

To clarify the characteristics of households with high exposure to both markets, we run a Probit estimation on the selection into risk profile 1, i.e. households highly exposed to the stock and mortgage market. Table 4 contains the average partial effects of household characteristic from the probit estimation. It follows that households with a high exposure to both markets in 2007 tend to be young or middle-aged households with lower income, higher education, and residing in Copenhagen, the capital and largest city in Denmark. This is intuitive. Young and middle-aged household will be overrepresented because debt levels typically decreases with age: first-time buyers are typically young households who will later pay down their debt. Hence, lower-income households are more likely to be included in risk profile 1. Consistent with existing literature showing that financial sophistication is important for the mortgage and investment decision, we find that households with the highest education tend to borrow more and invest more. The regional difference is a natural consequence of higher property prices in Copenhagen. The characteristics of households with high-risk levels towards both markets demonstrate the importance of controlling for household specifics when we estimate the consumption effect of risk attitudes.

4.1 Identification

To estimate the effect of risk allocation on consumption, we use the Triple Difference (TD) estimation, specified as

$$\begin{aligned} log(cons_{it}) =& \beta_0 + \beta_1 D_t^{\text{time}} + \beta_2 D_i^{\text{highMTI}} + \beta_3 D_i^{\text{highRAS}} \\ &+ \delta_1 D_t^{\text{time}} D_i^{\text{highMTI}} + \delta_2 D_t^{\text{time}} D_i^{\text{highRAS}} + \delta_3 D_i^{\text{highMTI}} D_i^{\text{highRAS}} \\ &+ \delta_4 D_t^{\text{time}} D_i^{\text{highMTI}} D_i^{\text{highRAS}} \\ &+ \xi' C_{i,2007} + u_{it}, \end{aligned} \tag{3}$$

where $cons_{it}$ is household consumption, D_i^{highMTI} and D_i^{highRAS} are indicators for the exposure to the mortgage and stock market, respectively, and D_t^{time} is a time-dummy differentiating between years around an economic shock to the markets.[11] Both D_i^{highMTI} and D_i^{highRAS} are constant over time for household i. The below annual threshold for market exposure is based on the 25%-percentile and the above 75%-percentile.[12] As mentioned above, we evaluate the consumption

[11] As explained in our consumption measure, we don't include stock holdings. This means that if households buy and sell stocks, we see an effect on the bank account, but not on the stock holdings, thereby influencing our consumption measure. Our underlying assumption is that households with low and high risky-asset-ratios have the same tendency to trade stocks during our sample period.

[12] Similar results are obtained using various thresholds of low and high exposure, i.e. below 30%-percentile against above 70%-percentile, below 35%-percentile against above 65%-percentile, and below 40%-percentile against above

effect around the eruption of the financial crisis in the 2008, so $D_t^{\text{time}} = 1$ for year 2008 and $D_t^{\text{time}} = 0$ for year 2007. We return to long-term consumption effects in section 5.1. $C_{i,2007}$ is the vector of control variables for household i. We control for age, mortgage type (whether the mortgage is an interest-only mortgage or not), income, number of adult residents, whether kids are living at home, relationship status, gender, educational level, as well as regional effects. All control variables are represented by their 2007-levels to ensure that the consumption effect is not driven by changes in controls. We only include households holding stocks in both 2007 and 2008, to exclude consumption effects of exits from the stock market. We require the households to hold ARMs that reset the interest rate a least once a year in both 2007 and 2008 to avoid consumption effects of shifts in mortgage type.

4.1.1 The consumption effects

The triple difference stated in equation (3) deserves further elaboration. Differentiating between the risk exposure to both the mortgage and stock market allows us to differentiate between the consumption effect for households with a high-risk profile towards both markets and the consumption effect for households with a high-risk profile towards one of the markets only. In short, we are interested in three effects. The main coefficients are δ_1, δ_2, and δ_4, and the main consumption effects of interest are

- $\delta_1 + \delta_2 + \delta_4$ (Total consumption effect)

  The consumption effect of the economic shocks in 2008 for households being highly exposed to shocks in both market (risk profile 1) relative to those only little exposed to changes in any of the markets (risk profile 4).

- $\delta_1 + \delta_4$ (Consumption effect of liability exposure)

  The consumption effect of the economic shocks in 2008 for households highly exposed to shocks in the mortgage market compared to those only little exposed to shocks in the mortgage market, given that all households are exposed to shocks in the stock market (risk profile 1 against risk profile 2).

- $\delta_2 + \delta_4$ (Consumption effect of asset exposure)

  The consumption effect of the economic shocks in 2008 for households highly exposed to shocks in the stock market compared to those only little exposed to shocks in the stock market, given that all households are exposed to shocks in the mortgage market (risk profile 1 against risk profile 3).

[Table 5 about here.]

60%-percentile. The results are available upon request.

The derivations of the three effects are presented in Table 5. Each of δ_1 and δ_2 shows the consumption effect of the economic shocks in 2008 for households highly exposed to one of the markets and little exposed to the other market relative to households little exposed to both markets. δ_1 refers to the consumption effect for households with high exposure towards the mortgage market and δ_2 the stock market. δ_4 shows the additional consumption effect of the economic shocks in 2008 for households being highly exposed to both markets. So, in total, the sum of the three coefficients $(\delta_1 + \delta_2 + \delta_4)$ shows the effect of the economic shocks in 2008 on consumption for households highly exposed to both markets relative to those only little exposed to both market. $\delta_1 + \delta_4$ $(\delta_2 + \delta_4)$ shows the consumption effect for households exposed to both markets against households with low exposure to the mortgage market (the stock market) and high exposure to the stock market (the mortgage market), which we refer to as the consumption effect of liability exposure (the consumption effect of asset exposure).

4.2 Results

[Table 6 about here.]

Table 6 presents the total consumption effect, the consumption effect of liability exposure, and the consumption effect of asset exposure from the triple difference stated in Equation (3). We find that households with risky positions on both the mortgage and the stock market (e.g. high-risk exposures, risk profile 1) reduce consumption in 2008 by 20.5% more than households with low-risk positions (risk profile 4). Obviously, a 20% cut-back in consumption during the course of one year is an economically very large consumption effect.

The main point of our paper is to quantify the extra effect of being exposed to both the asset and the liability side of the balance sheet, compared to being exposed to one side of the balance sheet only. Table 6 shows that consumption in 2008 is reduced by 11.2%-points more for households highly exposed to changes in both markets, compared to households highly exposed to changes in the stock market but only little exposed to changes in the mortgage market. Similarly, consumption in 2008 is reduced by 10.0%-points more for households highly exposed to changes in both markets, compared to households highly exposed to changes in the mortgage market but only little exposed to changes in the stock market.

We find that the consumption effect of asset and liability exposure do not depend on the risk exposure towards the other market. Regardless of whether households have a high or low risk level on one market, the consumption effect of high exposure towards the second market is not significantly different. The consumption effect of asset exposure for households with high-risk positions in the mortgage market is -10.0% and it is -9.3% for households with low-risk positions in the mortgage market. Similarly, for the consumption effect of liability exposure, consumption decreases around 11% more (11.2% and 10.5%) for households with risky positions in the mortgage market than for those with low-risk positions, regardless of the level of risk taken in the stock market. This illustrates that there is no strengthened nor more lenient effect of being exposed to

both markets, meaning that the total consumption effect is the sum of the consumption effect of asset exposure and liability exposure. But it is important to emphasize that households highly exposed to both markets will be hurt to a greater extend when a bad shock hits both market, because they are hurt by the sum of the consumption effects of shocks from both markets. In this case, a household highly exposed to both markets is hurt twice as hard as is a household only exposed to one market.

So overall, these results imply that households who chose a high-risk position in one market cut down their consumption by an already dramatic 10% during the financial crisis, compared to households choosing low-risk exposure on both markets. The financial crisis in this sense had a large negative effect on the consumption of households choosing a risky position in the mortgage or the stock market. If households are highly exposed to both markets, however, they reduce consumption by 10%-points more than the already large consumption cut-back for households exposed to one market only. This means that we find an amplified consumption effect from being exposed to negative shocks to both markets, compared to being exposed to one side of the balance sheet only. Our findings thus reveal that it can have large negative consequences for consumption in times of economic turbulence if households choose high-risk profiles on both the asset and liability markets.[13]

Existing literature typically focus on one market at the time. Using Swedish household-level data from 1999-2007, Di Maggio et al. (2020) find that an unrealized capital gain increases household consumption, while Di Maggio et al. (2017) show that a decline in mortgage payments caused by a fall in interest rates increases spending on car purchases. Both papers show an effect of a change in the stock market or a change in mortgage market on consumption. Relative to our setting, though, they focus - so-to-say - on the consumption effects of 11% or 10%. We show that it is important to account for both markets, as the tendency to choose a high-risk level in the stock and mortgage markets correlates positively. This positive correlation increases the overall risk of the household. We find that it amplifies the total consumption reduction of a negative economic shock. As both the stock and the mortgage market is hit by a bad economic shock in 2008 simultaneously, household consumption is not only reduced by 11.2% or 10.0%, but almost twice as much (-20.5%), for households highly exposed to both markets.

5 After-shock effect

In the previous section, we estimate the contemporaneous consumption effect of negative shocks to assets and liabilities. In this section, we analyse how long households are affected by the negative economic shocks, e.g. whether it is an immediate effect or it persists.

[13]For completeness, we rerun the consumption analysis for fixed rate mortgages, and finds non-negative consumption effects of liability exposure.

5.1 Persistency of consumption effect

To estimate the effect on consumption over time, we rerun the triple difference regression stated in Equation (3) using future consumption (in 2009, 2010, and 2011). By doing so, we capture the cumulative consumption effect over time. We use the same controls as for the triple difference regression in Equation (3). The results are presented in Table 7 and Figure 2. Table 7 shows the total consumption effect, the consumption effect of assets, and the consumption effect of liabilities. Figure 2 plots the absolute total consumption effect over time from 2008 to 2011. Hence, it includes both the immediate total consumption effect from 2008 (Table 6) and future total consumption effect from 2009 to 2011 (Table 7).

[Table 7 about here.]

[Figure 2 about here.]

Both Table 7 and Figure 2 illustrate that the amplified total consumption effect persists over time. The total consumption effect remains negative and significant until 2011, with diminishing effect over time. The economic shocks in the mortgage and stock market in 2008 reduce consumption by 22.3% from 2007 to 2009, 12.2% from 2007 to 2010, and 13.2% from 2007 to 2011 for households highly exposed to both markets relative to those only little exposed. Relative to the reduction in consumption during 2008 of 20.5%, the reduction in consumption is intensified further in 2009. The following two years, the total consumption effect is diminished. However, even in 2011 the economic shocks from 2008 still affect the household consumption considerably, as it explains a 13.2% reduction in consumption relative to 2007.

The persistency of the total consumption effect is driven by the asset market. Whereas the consumption effect of liability exposure is insignificant and does not persist after 2008, the consumption effect of asset exposure is highly significant after 2008, both in economic and statistical sense. To examine these findings in more detail, we next investigate the behavior on the two markets.

5.2 Behavior in the stock and mortgage market

Figure 3 illustrates the behavior in the stock and the mortgage market from 2007 to 2011 for different risk profiles. Figure 3a shows the stock market participation rate for households highly exposed to the stock market in 2007.[14] In 2007, we restrict the analysis to only include stock market participants, so naturally all households hold stocks in 2007. The figure shows that 7% of the households with risky positions in both the mortgage and the stock market sell all their stocks (93% still hold stocks) in 2008. In 2009 and 2010, only 88% still hold stocks, and in 2011, the stock

[14] Unfortunately, we do not have detailed information on the equity portfolio of the household, implying that we cannot track changes in the individual positions of the portfolio. However, we know the total market value of all the stock holdings of the individual, so we are able to track exit of the stock market.

market participation rate has decreased further to 85%. For the same period, the stock market participation rate is higher for households highly exposed to the stock market and little exposed to the mortgage market. In 2008, around 4% exit the stock market i.e. 96% still hold stocks. During 2009 to 2011, the stock market participation rate decreases further, to 92% in 2011.

[Figure 3 about here.]

Consistent with prior literature (e.g. Kaustia and Knüpfer (2008), Malmendier and Nagel (2011), Bucher-Koenen and Ziegelmeyer (2014), and Andersen et al. (2019)), we generally find that investors tend to cut losses. The striking tendency illustrated in Figure 3a is the behavioral difference between households with different risk positions in the mortgage market (remember that all households in Figure 3a have a high-risk position in the stock market). During the four years, 15% of the households with risky positions in both markets sell all their stocks, whereas it is only the case for 8% of the households with risky positions in the stock market but risk-less positions in the mortgage market. This illustrates that households are more likely to leave the stock market if they are also highly exposed to the negative shock in the mortgage market in 2008. It highlights that taking a high risk on both markets is not only hurting households more in terms of consumption, but as a result these households tend to stop investing in stocks to a greater extent than households only being highly exposed to the stock market.

This investment behavior may reflect a learning pattern or a need for liquidity. From the bad shock in 2008, some households with high-risk allocations towards both markets may learn that the total financial risk of the household is too high. To reduce the total risk, those households may find it beneficial to leave the stock market. Alternatively, it may reflect a need for liquidity where households highly exposed to both markets are forced to sell stocks to cover higher payments on mortgage loans. To investigate this further, we repeat Figure 3a for each quartile of the liquid asset ratio in 2007. The results are presented in Figure 4. The liquid asset ratio is defined as the market valuation of bonds and stocks plus the bank account as a percentage of the total asset. Total assets include all liquid asset and the property value.

[Figure 4 about here.]

From Figure 4, we see that households with the lowest liquid asset position drive the difference in investment behavior from 2007 to 2011 across risk profiles in 2007. This indicates that the behavior most likely reflects a need for liquidity, i.e. a situation where households with risky positions in both markets sell all their stocks to cover higher mortgage payments after the economic shock in 2008. Interestingly, this offers an alternative explanation for why investors tend to sell assets whose value have deteriorated. Whereas prior literature such as Kaustia and Knüpfer (2008), Malmendier and Nagel (2011), Bucher-Koenen and Ziegelmeyer (2014), and Andersen et al. (2019) argue that investors tend to cut losses, we argue that it may simply be driven by a need for liquidity.

We cannot rule out the learning pattern. The households with the lowest liquid asset positions are also the households who are most likely to learn that they have taken a too high risk because the simultaneous bad shocks towards both the stock and mortgage market are likely to hit those households relatively more. Consequently, those households are more likely to leave the stock market.

For completeness, we also examine the behavior in the mortgage market. We expect the reaction on the mortgage market to be minimal relative to the stock market. The reason is that the household must refinance its mortgage or leave the mortgage market altogether, i.e. fully repay the mortgage or move from their home, both of which involves significant transaction costs, if the household wants to change its risk level towards the mortgage market. Relatively few will have sufficient liquid assets to repay the mortgage, so changing the risk level towards the mortgage market involve relative high personal costs (moving from home) or monetary costs (refinancing the mortgage). Decreasing the risk taken in the stock market by exiting the stock market or changing the portfolio of stocks is relatively cheaper. Figure 3b plots the fraction of adjustable rate mortgages for households with high exposure to the mortgage market in 2007. We find no statistically significant change in behavior regarding the choice of mortgage type for households highly exposed to the mortgage market, as expected.

Overall, we find that the amplified consumption effect we have estimated is not only immediate, but persists over time. Additionally, households highly exposed to the negative economic shock to the stock market in 2008 tend to exit the stock market to a greater extend if they are also highly exposed to the negative economic shock to the mortgage market in 2008. This may reflect a learning pattern, where the household reduces the household's total risk by selling stocks, or a need for cash to cover mortgage payments. The latter may also explain why investors tend to leave the stock market when risky assets perform badly. Whereas existing literature refers to the tendency as an attempt to cut losses, it could also be driven by a need for liquidity. The same exit is not found in the mortgage market, as expected.

6 Summary and conclusion

Existing literature shows that households adjust consumption in response to stock market losses and interest rate changes, treating the two channels separately. Sometimes though, for instance during financial crises, both stock markets and mortgage rates move together, influencing both the asset and liability side of the household's balance sheet. For the household, and from a broader financial stability/macroprudential policy point of view, it is important to know not only how households adjust spending in relation to stock market or mortgage rates changes, but also how they adjust if both markets are negatively affected at the same time. This is a complicated task, however, as it requires detailed data on households' stock market exposure, mortgage rate exposure, and level of consumption for a sufficiently large sample. It also requires a shock to both stock and mortgage markets, such that the effects can be identified. Using detailed household

data from Denmark, including information on mortgages, stock market exposure, and imputed consumption, this paper studies how households adjust their consumption in response to adverse stock and mortgage market movements during the financial crisis of 2008.

We find that households who have a risky position in either the stock market or the mortgage market cut consumption by almost ten percent following the financial crisis. We also find, as our main result, that households who have a risky position in both markets cut consumption by almost the double. This is arguably a large consumption loss. Adding to this effect, we also show that households who tend to choose a risky position in the mortgage market also tend to choose a risky position in the asset market.

We find that the consumption effects persist for several years. People also react to the shocks in other ways, as some households leave the stock market after experiencing the negative shocks of the financial crisis. Households highly exposed to both the mortgage and the stock markets are more likely to leave the stock market, we find.

Our findings relate to crises periods, i.e. what happens to consumption during times of crises. There is of course a reason why people choose to take risky positions in both the mortgage and the stock markets in the first place. When times are good, i.e. stock markets rise and interest rates remain low, these households benefit. It would be an interesting avenue for future research to try to relate the costs of high-risk exposure during crises to the potential gains during non-crises periods, as well as study potential heterogeneous costs-benefit trade-offs across different types of households. Such an analysis would at the same time be challenging to conduct, though, as it would require identification of both the positive and the negative externalities of high-risk exposures. Our paper has taken the first step, evaluating the cost of high-risk exposures during crises.

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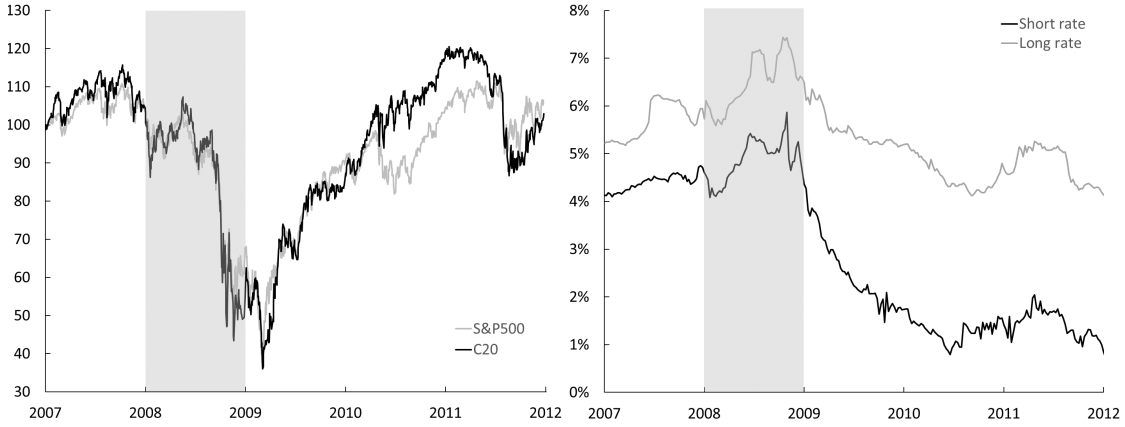


(a) OMX Copenhagen 20 and S&P500 **(b)** Average Danish mortgage rates

Figure 1: The mortgage and stock market. The figure presents the weekly average Danish mortgage rate and the daily closing price for OMX C20 and S&P500. The mortgage rates are calculated on a weekly basis and show the average yield-to-maturity on mortgage-backed bonds denominated in Danish Kroner. The closing price for OMX C20 and S&P500 are based on daily data. OMX C20 is a stock index for the twenty most traded stock on NASDAQ. Both indices are indexed at base value 100 on January 2, 2007. Data source: Mortgage data from Finance Denmark, historical data on OMX C20 from NASDAQ, and historical data on S&P500 from Yahoo Finance, from 2007 to 2011.

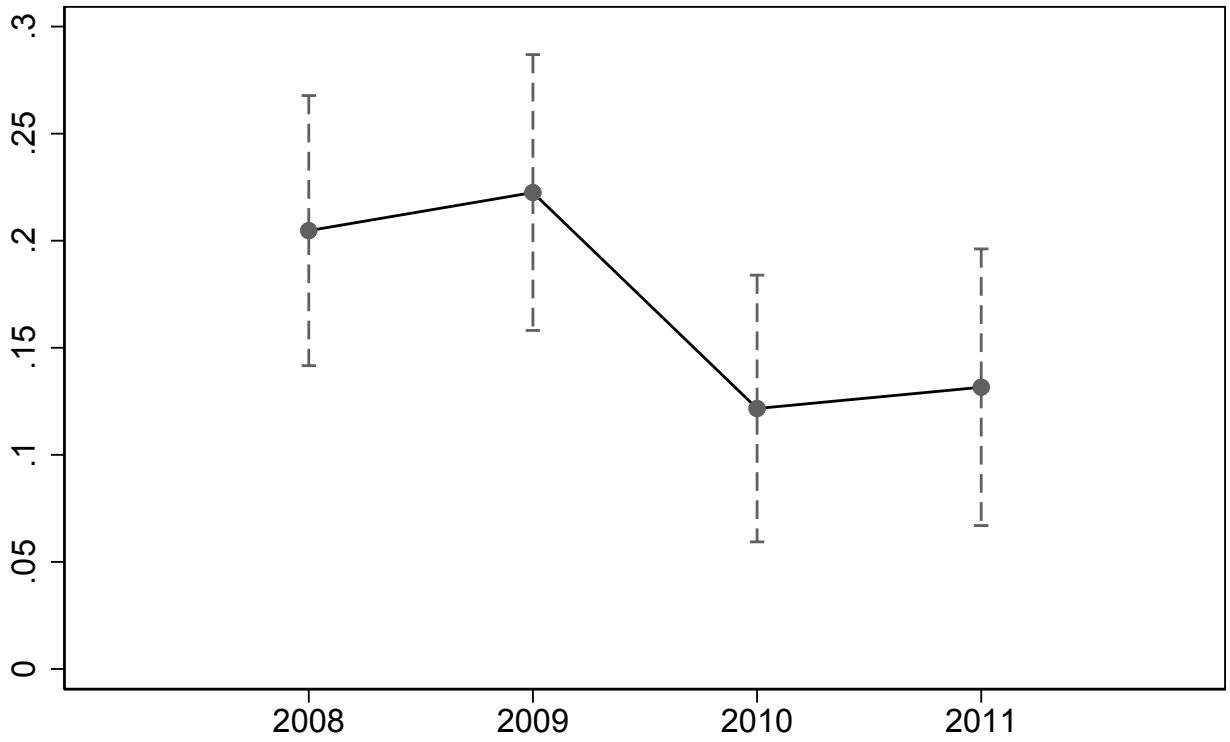
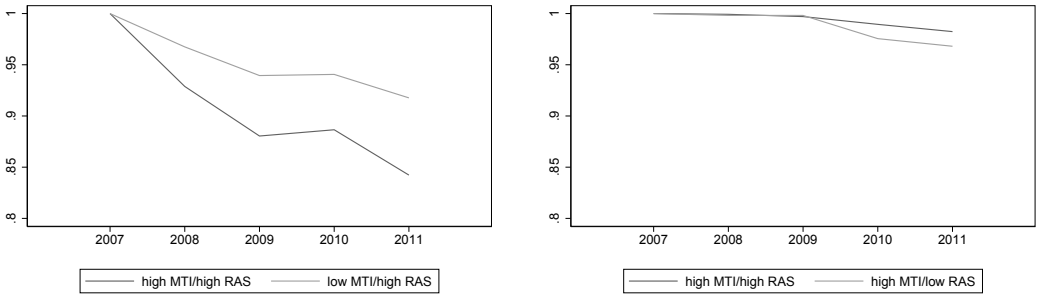


Figure 2: Persistency of the total consumption effect in absolute terms. The figure presents the absolute total consumption effects and the 95% confidence interval for the total consumption effect, from 2008 to 2011. It includes both the immediate total consumption effect from 2008 (Table 3) and future total consumption effect from 2009 to 2011 (Table 7).



(a) Fraction of stock market participation

(b) Fraction of adjustable rate mortgages

Figure 3: Behavior in the stock and mortgage market across risk profiles. The graph presents the annual fraction of households holding stocks across households with *high* risky-asset-share and either *low* or *high* mortgage payment-to-income (Figure 3a), and the annual fraction of households with an adjustable-rate mortgage across households with *high* mortgage payment-to-income and either *low* or *high* risky-asset-share (Figure 3b). The *low* and *high* levels of mortgage payment-to-income and risky-asset-share are based on 2007-levels. Data source: Stock market participants with an adjustable rate mortgage that resets the interest rate at least once a year in 2007, on households level, 2007-2011.

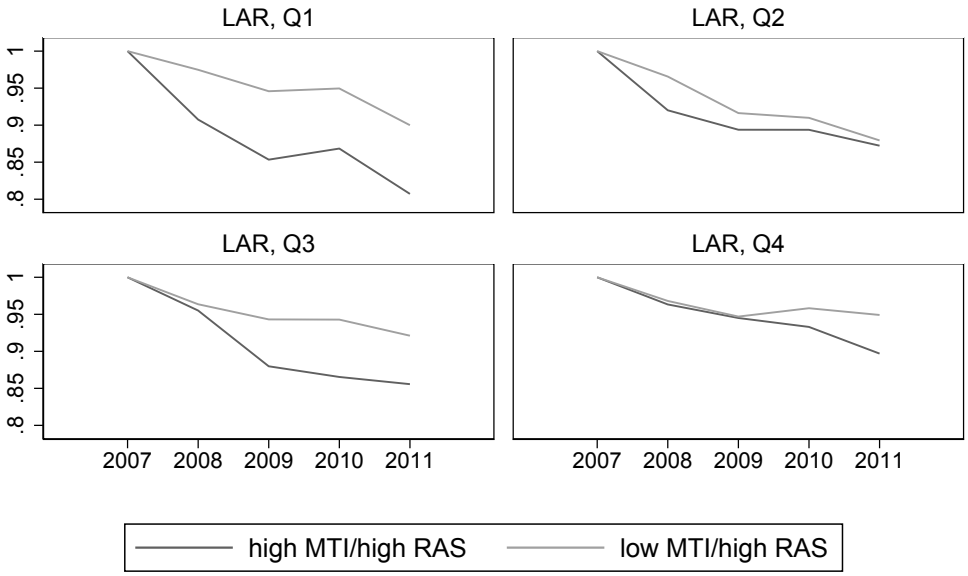


Figure 4: Stock market participation rate across risk profiles and liquid asset ratio (LAR). The graph presents the annual fraction of households holding stocks for households with *high* risky-asset-share and either *low* or *high* mortgage payment-to-income in 2007. The graph also differentiates between the quartiles of liquid asset ratio of which the household belong to in 2007. Data source: Stock market participants with an adjustable rate mortgage that resets the interest rate at least once a year in 2007, on households level, 2007-2011.

	2007		2007-2011	
	Mean	SD	Mean	SD
Asset Market				
Stock market participation	1.000	0.000	0.938	0.209
Risky Asset Share	0.317	0.278	0.230	0.256
Debt Market				
Total debt	578.517	463.026	622.786	505.964
Mortgage debt	446.335	354.420	494.286	413.187
Debt-to-asset	0.530	0.346	0.602	0.396
Loan value-to-income	3.252	17.877	3.336	69.427
Mortgage payment-to-income	0.195	0.122	0.168	0.108
Interest-only mortgage	0.285	0.451	0.307	0.461
Adjustable rate mortgage	0.438	0.496	0.473	0.498
Nom. interest rate (%)	4.934	1.279	4.073	1.511
Demographics				
Income	155.448	57.078	175.238	66.958
Age	50.123	13.170	52.128	12.927
Single	0.166	0.372	0.157	0.363
Male	0.912	0.284	0.914	0.281
Number of adult residents	1.819	0.390	1.830	0.379
Number of kids	0.814	1.040	0.814	1.048
Education level 1	0.102	0.302	0.098	0.297
Education level 2	0.437	0.496	0.430	0.495
Education level 3	0.462	0.499	0.472	0.499
Region Copenhagen	0.210	0.407	0.207	0.405
Region Zealand	0.150	0.357	0.150	0.357
Region South Denmark	0.264	0.441	0.265	0.441
Region Middle Jutland	0.229	0.420	0.230	0.421
Region North Jutland	0.147	0.354	0.148	0.355
Observations	83,083		367,921	
Unique households	83,083		83,083	

Table 1: Summary statistics. The table presents average values and standard deviations of loan- and household-specific variables. Loan variables are all related to the dominant mortgage of the household, i.e. the mortgage with the highest loan amount. Debt, loan amounts, and income are in DKK 1,000, and measured as an average per adult in the household. All variables are presented in 2020-prices. The summary statistics for 2007-2011 are measured as average annual statistics. The table includes stock market participants with a mortgage in 2007, on households level, from 2007 to 2011.

	Risky Asset Share		Risky Asset Share	
Debt-to-asset (SD-adj.)	0.018***	(0.001)	0.026***	(0.001)
Mortgage payment-to-income (SD-adj.)	0.016***	(0.001)	0.012***	(0.001)
Adjustable rate mortgage	0.033***	(0.002)	0.030***	(0.002)
Interest-only mortgage	0.010***	(0.004)	0.009**	(0.004)
Interest-only mortgage				
× Adjustable rate mortgage	-0.005	(0.005)	-0.003	(0.005)
Controls				
Average age			0.001***	(0.000)
Male			0.058***	(0.005)
Single			-0.013*	(0.008)
Log of Income (SD-adj.)			0.032***	(0.004)
Number of adult residents			-0.087***	(0.008)
dummy for kids in household			0.032***	(0.002)
Education level 2			0.013***	(0.003)
Education level 3			0.025***	(0.004)
Zealand			-0.029***	(0.003)
South Denmark			-0.035***	(0.003)
Middle Jutland			-0.017***	(0.003)
North Jutland			-0.045***	(0.004)
Constant	0.247***	(0.002)	0.255***	(0.018)
Observations	80,295		80,295	
R-squared	0.016		0.030	
Adj. R-squared	0.016		0.030	

Standard errors in parentheses

$^{*}(p < 0.10),^{**}(p < 0.05),^{***}(p < 0.01)$

Table 2: OLS of risky-asset-share on debt-to-asset, mortgage payment-to-income, mortgage type, and controls in 2007. The table presents coefficients and robust standard errors for the OLS estimation of risky-asset-share on debt-to-asset ratio, mortgage payment-to-income, mortgage type, and controls (average age, gender, relationship status, income, number of adult residents, dummy for kids living at home, educational level, and regions). All variables are presented in 2020-prices. The regression is stated in Equation (1). Data source: Stock market participants with a mortgage, on households level, 2007.

Risk profile	1	2	3	4
Level of risky-asset-share	*High*	*High*	*Low*	*Low*
Level of mortgage payment-to-income	*High*	*Low*	*High*	*Low*
Risky Asset Share	0.79	0.78	0.04	0.04
	(0.14)	(0.14)	(0.03)	(0.03)
Mortgage payment-to-income	0.39	0.09	0.38	0.09
	(0.13)	(0.03)	(0.12)	(0.03)
Total debt	1042.81	541.85	877.41	372.11
	(496.90)	(433.84)	(431.24)	(330.07)
Income	136.87	178.37	125.33	159.13
	(54.11)	(63.93)	(47.24)	(56.14)
Consumption	171.29	174.41	134.37	136.39
	(102.48)	(100.90)	(101.34)	(87.41)
Value of stocks	129.72	135.88	6.51	6.44
	(139.76)	(137.35)	(9.52)	(10.99)
Nom. interest rate (%)	4.88	4.77	4.95	4.89
	(0.32)	(0.36)	(0.30)	(0.37)
Observations across treatment groups	869	820	629	1058

Standard errors in parentheses

Table 3: Summary statistics by levels of risk towards the stock and mortgage market in 2007. The table presents the average values and standard deviation of key factors for the construction of the risk profiles. The statistics are included for each group of risk profiles. Total debt, income, consumption, and the market value of stocks are in DKK 1,000, and measured as an average per adult in the household. All variables are presented in 2020-prices. Data source: Stock market participants with an adjustable rate mortgage that resets the interest rate at least once a year, on households level, 2007.

-34	0.008	(0.032)
35-39	0.047	(0.032)
40-44	-0.011	(0.029)
50-54	-0.025	(0.031)
55-59	-0.090***	(0.031)
60-64	-0.106***	(0.032)
65-69	-0.135***	(0.034)
70-	-0.187***	(0.031)
Male	0.051*	(0.027)
Single	-0.020	(0.052)
Log income	-0.268***	(0.023)
Number of adult residents	-0.218***	(0.052)
Dummy for kids in household	0.055***	(0.021)
Education level 2	0.035	(0.026)
Education level 3	0.088***	(0.027)
Zealand	-0.148***	(0.025)
South Denmark	-0.227***	(0.021)
Middle Jutland	-0.117***	(0.024)
North Jutland	-0.309***	(0.022)
Observations	3,351	
Pseudo-R-squared	0.141	

Standard errors in parentheses

$^{*}(p < 0.10),^{**}(p < 0.05),^{***}(p < 0.01)$

Table 4: Probit of selection into the risk profile of high mortgage payment-to-income and high risky-asset-share on household specifics. The table presents average partial effects of household specifics from a probit estimation on selection into the risk profile of high exposure to both the stock and mortgage market. Income is measured in 2020-prices. Data source: Stock market participants with an adjustable rate mortgage that resets the interest rate at least once a year, on households level, 2007.

		$D_i^{highMTI} = 0$ & $D_i^{highRAS} = 0$	$D_i^{highMTI} = 1$ & $D_i^{highRAS} = 1$	Difference
D_t^{time}	0	β_0	$\beta_0 + \beta_2 + \beta_3 + \delta_3$	$\beta_2 + \beta_3 + \delta_3$
	1	$\beta_0 + \beta_1$	$\beta_0 + \beta_1 + \beta_2 + \beta_3 + \delta_1 + \delta_2 + \delta_3 + \delta_4$	$\beta_2 + \beta_3 + \delta_1 + \delta_2 + \delta_3 + \delta_4$
Difference		β_1	$\beta_1 + \delta_1 + \delta_2 + \delta_4$	$\delta_1 + \delta_2 + \delta_4$

(a) Total consumption effect

		$D_i^{highMTI}$		Difference
		0	1	
D_t^{time}	0	$\beta_0 + \beta_3$	$\beta_0 + \beta_2 + \beta_3 + \delta_3$	$\beta_2 + \delta_3$
	1	$\beta_0 + \beta_1 + \beta_3 + \delta_2$	$\beta_0 + \beta_1 + \beta_2 + \beta_3 + \delta_1 + \delta_2 + \delta_3 + \delta_4$	$\beta_2 + \delta_1 + \delta_3 + \delta_4$
Difference		$\beta_1 + \delta_2$	$\beta_1 + \delta_1 + \delta_2 + \delta_4$	$\delta_1 + \delta_4$

(b) Consumption effect of liabilities ($D_i^{highRAS} = 1$).

		$D_i^{highRAS}$		Difference
		0	1	
D_t^{time}	0	$\beta_0 + \beta_2$	$\beta_0 + \beta_2 + \beta_3 + \delta_3$	$\beta_3 + \delta_3$
	1	$\beta_0 + \beta_1 + \beta_2 + \delta_1$	$\beta_0 + \beta_1 + \beta_2 + \beta_3 + \delta_1 + \delta_2 + \delta_3 + \delta_4$	$\beta_3 + \delta_2 + \delta_3 + \delta_4$
Difference		$\beta_1 + \delta_1$	$\beta_1 + \delta_1 + \delta_2 + \delta_4$	$\delta_2 + \delta_4$

(c) Consumption effect of assets ($D_i^{highMTI} = 1$)

Table 5: Derivation of consumption effects of interest, described in section 4.1.1.

Total consumption effect ($\delta_1 + \delta_2 + \delta_4$)	-0.197***	-0.205***
	(0.038)	(0.032)
Consumption effect of liability exposure		
Given high exposure to asset market ($\delta_1 + \delta_4$)	-0.111***	-0.112***
	(0.039)	(0.032)
Given low exposure to asset market (δ_1)	-0.065	-0.105***
	(0.045)	(0.039)
Consumption effect of asset exposure		
Given high exposure to debt market ($\delta_2 + \delta_4$)	-0.132***	-0.100**
	(0.048)	(0.042)
Given low exposure to debt market (δ_2)	-0.086**	-0.093***
	0.035)	(0.029)
2007-level controls	Excl.	Incl.
Observations	6,578	6,532
R-squared	0.031	0.310
Adj. R-squared	0.030	0.308

Standard errors in parentheses

$^{*}(p < 0.10),^{**}(p < 0.05),^{***}(p < 0.01)$

Table 6: Triple difference estimations. The table presents the linear combinations of partial effects and robust standard errors (in brackets) from the triple difference estimation stated in Eg. (3). Description of the linear combinations of partial effects are presented in section 4. The dependent variable is household consumption per adult in the household. The regressions in the last column controls for age, mortgage type (IO or not), gender, relationship status, income, number of residents, dummy for kids living at home, educational level, and regions. All variables are inflation-adjusted and presented in 2020-prices. The table includes stock market participants with an adjustable rate mortgage that resets the interest rate at least once a year in both 2007 and 2008, on households level.

	2009	2010	2011
Total consumption effect ($\delta_1 + \delta_2 + \delta_4$)	-0.223***	-0.122***	-0.132***
	(0.033)	(0.032)	(0.033)
Consumption effect of liability exposure ($\delta_1 + \delta_4$)			
Given high exposure to asset market ($\delta_1 + \delta_4$)	-0.046	-0.036	0.030
	(0.034)	(0.033)	(0.034)
Given low exposure to asset market (δ_1)	-0.037	0.011	-0.011
	(0.037)	(0.037)	(0.038)
Consumption effect of asset exposure ($\delta_2 + \delta_4$)			
Given high exposure to debt market ($\delta_2 + \delta_4$)	-0.186***	-0.133***	-0.121***
	(0.041)	(0.040)	(0.041)
Given low exposure to debt market (δ_2)	-0.177***	-0.158***	-0.161***
	(0.030)	(0.030)	(0.030)
2007-level controls	Incl.	Incl.	Incl.
Observations	6,214	6,055	5,871
R-squared	0.312	0.329	0.336
Adj. R-squared	0.310	0.327	0.334

Standard errors in parentheses

*($p < 0.10$),** ($p < 0.05$),*** ($p < 0.01$)

Table 7: Persistency of the consumption effect. The table presents the linear combinations of partial effects and robust standard errors (in brackets) from the *persistency* estimation described in section 5.1. Description of the linear combinations of partial effects are presented in section 4. The dependent variable is future household consumption per adult in the household in 2009, 2010, and 2011. The regressions control for age, mortgage type (IO or not), gender, relationship status, income, number of residents, dummy for kids living at home, educational level, and regions. All variables are inflation-adjusted to represent 2020-prices. The table includes stock market participants with an adjustable rate mortgage that resets the interest rate at least once a year in 2007 and 2008, on households level, 2007-2011.

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