Heterogeneous Mortgage Choice: Evidence from Denmark

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Abstract

We provide new facts on the cross-sectional determinants of mortgage choice using comprehensive administrative data from Denmark. Several of these facts are at variance with the predictions of standard models of mortgage choice. Based on these observations, we build a new lifecycle model of mortgage choice in which households can choose between an FRM and an ARM. The model delivers predictions that are closer to the data. Despite this advance, substantial "dark matter" remains, in the sense that a rich set of conditioning variables provides relatively low explanatory power for observed household mortgage choices.

1 Introduction

A commonplace observation is that different people make different financial decisions. What puzzles financial economists is that the heterogeneity in household financial choices is often difficult to rationalize using standard finance theories.

The choice of a mortgage is a particularly important decision, given the prevalence of mortgage borrowing, the large size of mortgages relative to other household liabilities, and the role of mortgages in the transmission of monetary policy.[1] While some countries have a single dominant mortgage form, in other countries both adjustable-rate mortgages (ARMs) and fixed-rate mortgages (FRMs) are common. In the US, for example, FRMs generally dominate but ARMs are popular in some periods: Badarinza, Campbell, and Ramadorai (2018) report that in the period 1992–2013, the ARM share in the US was as high as 38% in the early 1990s and was also substantial during the credit boom of the early 2000s. Many other countries in their study have ARM shares that are far from zero or one. In Denmark, for example, the ARM share varied from 14% to 73% during the decade from 2003–2013.

The coexistence of ARMs and FRMs raises the question of which households choose adjustable rates over fixed rates, and why. The choice has implications for monetary policy transmission, as a cut in interest rates directly relaxes the budget constraints of ARM borrowers but only benefits those FRM borrowers who refinance their mortgages. We study this question using data from Denmark, whose mortgage system is comparable to the US system in many respects but which offers several advantages for such an investigation. High-quality administrative data are available on the entire cross-section of Danish households and mortgages (Andersen et al. 2020), and Danish mortgage regulation is simpler than the complex US system. Particularly important for our purposes, there is no Danish equivalent of the GSE credit guarantees that lower the cost of FRMs for conforming US borrowers and may distort cross-sectional patterns of mortgage choice.

Theory suggests a number of reasons why households may differ in their mortgage choices, and we find empirical evidence to support the relevance of many of these considerations. Since mortgages are financial instruments, we can rule out pure differences in tastes of the sort that may be relevant for purchases of goods and services including housing. Instead,

[1] Badarinza, Campbell, and Ramadorai (2016) report that 47% of US households in the 2010 Survey of Consumer Finances had a mortgage, and mortgage balances accounted for 53% of outstanding debt for the average household. Mortgage borrowing is also particularly widespread in Australia (37% of households have mortgages which on average account for 47% of outstanding debt), Canada (34% and 38%), Finland (33% and 46%), the Netherlands (44% and 60%), and the UK (36% and 51%) among the countries they study. Campbell (2013), Di Maggio et al. (2017), Greenwald (2018), Beraja et al. (2019), and Campbell, Clara, and Cocco (2021) are some of the many papers that emphasize the mortgage channel of monetary policy transmission.

we focus on differences across households in their personal economic circumstances and their beliefs about the economy. We take as given an environment in which the initial interest rate on an ARM is lower than the interest rate on a FRM. This is normally true, both because the term structure of interest rates is typically upward-sloping and because FRMs carry an option to refinance that further increases their initial interest rates; and it is true in Denmark throughout the period of our study. Of course, if interest rates rise after mortgage origination, then the rate payable on an ARM may become higher than the rate on a FRM that was originated at the same time.

A first relevant circumstance is the probability that a household will move in the near future. If a household moves, it must normally refinance its mortgage and this lowers the value of the option to refinance strategically that is embedded in a FRM. Heuristically, a household that will move pays most attention to the current difference in interest rates and is therefore more likely to choose an ARM.

A second consideration is the limit on mortgage borrowing imposed by mortgage lenders. Lenders typically restrict both the loan-to-value (LTV) ratio, the ratio of the mortgage balance to the market value of the house that serves as collateral for the mortgage loan, and the mortgage-payment-to-income (MTI) ratio, the ratio of monthly mortgage payments to income. If the MTI limit is binding, then the lower mortgage rate on an ARM allows a household to take out a larger mortgage and buy a larger home.

A third circumstance is a binding borrowing constraint that limits current consumption. Even at a fixed mortgage size, a lower initial interest rate allows higher current consumption which is particularly valuable for a household with minimal financial assets and borrowing capacity.

The three circumstances above are most likely to apply to young households with low financial assets. A fourth situation in which a household may prefer an ARM is very different. If a household has substantial financial assets and is interested in leveraging these investments, the most cost-effective way to do so is likely to be a mortgage. The high quality of housing collateral reduces the cost of mortgage borrowing, and mortgages unlike margin loans are not callable. An ARM is a particularly attractive way to take leverage because it has a low current interest rate; and if the ARM rate rises in the future, the household has the ability to delever and pay off the mortgage.

Beyond these differences in circumstances, different households may have different beliefs about the future evolution of the economy. Most obviously, a household that expects interest rates to rise rapidly is likely to want to lock in current rates using a FRM, whereas a household that expects interest rates to fall will expect an ARM to be cheaper. Beyond this, a household that expects house prices to rise rapidly is likely to want to buy a larger

house and may therefore be interested in relaxing the MTI constraint through the use of an ARM. Similarly, a wealthy household with optimistic expectations about financial market returns may be interested in leveraged investing financed by ARM borrowing.

Households may also have relevant information about their own future prospects. A household that expects rapid increases in its own income is likely to want to both buy a large house and increase current consumption. Both the MTI constraint and the borrowing constraint on current consumption are more likely to bind for such a household, leading it to prefer an ARM. On the other hand, a household that knows it is exposed to high risk of income fluctuations will be concerned about the possibility that high future interest rates will coincide with low future income, and will tend to prefer a FRM to limit its risk exposure. This FRM preference will be particularly strong if the household's income is negatively correlated with interest rates.

Finally, education and financial sophistication may affect mortgage choice if one type of mortgage requires more active risk management than another. This could discourage less educated borrowers from using ARMs, although the option to refinance a FRM is also challenging as Andersen et al. (2020) emphasize.

In this paper we ask which of these forces influence Danish borrowers to choose ARMs over FRMs. While we find evidence that many of these effects are operative, we also note findings that are at variance with the predictions of standard models, as well as novel findings that have not been considered in models of mortgage choice. Motivated by these facts, we build a rich lifecycle model of mortgage choice to advance our understanding of household motivations.

Notable patterns in the Danish data that are aligned with canonical predictions include the fact that ARM choice is associated with a higher probability of a subsequent move, although this is not the case for borrowers with high levels of debt relative to their income who may choose ARMs to alleviate constraints regardless of whether they intend to move or not. Using survey data to measure beliefs, we also find that households who expect higher inflation are more likely to choose FRMs while those who expect their own financial situation to improve are more likely to choose ARMs.

While mortgage choice in Denmark aligns with the predictions of the literature in several dimensions, other observations from the data are more puzzling. For example, we find that youth and realized future income growth (a proxy for expected income growth under the assumption of rational expectations) do not predict ARM choice. As income tends to grow over the lifecycle, we would expect younger borrowers to have higher income growth expectations and therefore to choose ARMs to relax their current financial constraints which are anticipated to ease. We instead find that Danish data include a tendency for older

borrowers to choose ARMs. We also find that borrowers with larger mortgages tend to choose ARMs, which is at variance with the prediction that such borrowers will choose FRMs to reduce risk arising from nominal payment volatility.

An intriguing pattern in the data is a U-shaped relationship between the ARM share and net wealth. In the US, such a relationship might be explained by government support for FRMs among conforming mortgages taken out by borrowers with intermediate levels of wealth; however, this cannot be the explanation in Denmark. Our interpretation is that ARMs have a dual clientele that includes both borrowers with very low income and high bank debt, who are plausibly constrained, and borrowers with high financial assets who may be using ARMs to leverage financial investments.

Although these relationships between mortgage choice and observable household characteristics are statistically significant and economically meaningful, there remains a great deal of unexplained variation in mortgage choice. Even a rich saturated model that allows many observable variables to predict mortgage choice in a nonlinear fashion has relatively low explanatory power. Put another way, we are unable to construct a group, based on observable characteristics, for which the ARM share is close to zero or close to one. This implies that there must be other forces, economic "dark matter", that are important for households' mortgage decisions and that we are unable to measure.

In order to better understand what patterns in mortgage choice we should expect to find using the observables we do measure, we build a dynamic model of the consumption, investment, mortgage and housing choices of a utility-maximizing household with a finite lifetime. Households face uninsurable income risk, stochastic home prices, and may invest at the risk-free rate or in risky stock markets, as well as their position in housing. In addition, households face risky interest rates with a realistic term structure.

The household initially purchases a house, and must meet minimum down-payment and payment-to-income constraints. Crucially, the household may select a house from a ladder of potential home sizes, with a fixed minimum floor. Beyond the down payment, the household may finance the purchase with either a fixed or adjustable rate mortgage.

In all subsequent periods, the household must chose non-durable consumption, whether to invest their financial savings in stocks or one-period bonds, and manage their mortgage. If the household retains enough home equity or financial assets, they may refinance their FRM, or prepay their mortgage. Investors face an exogenous moving probability.

We use our Danish administrative microdata to calibrate the model, matching income processes, home sizes, mortgage spreads, and other features of a large sample of Danish mortgage borrowers. Additionally, we structure our model to match the key institutional features of

the Danish context, which includes a unique refinancing option for fixed rate mortgages, constraints on mortgage borrowers, and relative high tax income tax rates.

The model predicts that wealthier borrowers place higher value on ARMs at mortgage origination regardless of prevailing short rates, and use these funds to invest in risky assets, consistent with the hypothesized mechanism. In contrast, relatively poorer borrowers favor ARMs over FRMs when interest rates are high, and cost minimization is an imperative, preferring relatively safer (in nominal terms) FRMs when interest rates are lower.

The organization of the paper is as follows. The remainder of this section discusses related literature. Section 2 introduces the data and summary statistics. Section 3 discusses empirical evidence on mortgage choice in Danish data, with a specific focus on how the facts in the data line up with pre-existing theory. Section 4 sets up the model, and introduces the parameters that we use for calibration. Section 5 concludes.

Related literature

The academic literature on the choice between ARMs and FRMs is surprisingly small. On the theoretical side, an early paper by Alm and Follain (1987) emphasizes the covariance between household income and interest rates. Campbell and Cocco (2003) develops a life-cycle model that captures the effects of current borrowing constraints and concerns about future income risk. Corbae and Quintin (2015) and Greenwald (2018) model an MTI constraint, but do not apply it to mortgage choice.

On the empirical side, Koijen, Van Hemert, and Van Niewerburgh (2009) and Moench, Vickery, and Aragon (2010) study time-series variation in the ARM share in the US mortgage market. Badarinza, Campbell, and Ramadorai (2018) present a comparative international analysis of this question. Koijen, Van Hemert, and Van Niewerburgh (2009) posit that borrowers extrapolate current rates, and use such rules of thumb to inform their mortgage choices. While we do not explore this mechanism in the current version of the paper, in future, the model could be modified to incorporate such non-rational expectations.

The cross-section of mortgage choice was studied early on by Dhillon, Shilling, and Sirmans (1987) and Brueckner and Follain (1988) using very small US datasets with 78 and 475 household observations respectively. More recently, Coulibaly and Li (2009) and Johnson and Li (2014) have explored cross-sectional mortgage choice using US data from the Survey of Consumer Finances with 2,878 and 9,827 household observations respectively. Like us, these papers combine data on household circumstances and beliefs, but we are able to rely on a much larger administrative dataset with 1,163,574 household observations to estimate the effects of circumstances.

There are also a few recent papers that document particular determinants of mortgage decisions. Bailey et al. (2019) show that cross-sectional variation in house price expectations has a measurable influence on mortgage leverage, while Botsch and Malmendier (2020) argue that past experience of inflation affects beliefs about future inflation and hence mortgage choice.

2 Background and Data

2.1 Background: The Danish mortgage system

The mortgage system in Denmark has traditionally been dominated by long-term fixed rate mortgages (FRMs) without prepayment penalties, similar to the US market. These mortgages are originated by one of seven active mortgage credit institutions, who fund mortgages by issuing covered bonds collateralized by mortgage pools. The market for mortgage lending is competitive, and borrowers typically face similar mortgage rates and administration fees across mortgage banks.

Adjustable-rate mortgages (ARMs) were introduced in Denmark in the 1990s, and have grown to represent a sizable fraction of the market. Badarinza, Campbell, and Ramadorai (2018) report that the average share of adjustable-rate mortgages in Denmark was 45% in the period 2003–13, with a standard deviation of 13%. These mortgages have terms up to 30 years and typically feature annual interest rate adjustments, although three and five year intervals are also possible. In contrast to the US market, where rate adjustments are determined on the basis of an underlying financial index, adjustments in Denmark are determined directly by the market value of mortgage bonds. Prior to each adjustment date, mortgage banks redeem outstanding bonds and replace them with new bonds. The yield on newly issued bonds determines interest rate adjustments.

For both adjustable and fixed rate mortgages, Danish mortgage banks act as intermediaries between investors and borrowers and assume default risk. In the case of a borrower default, mortgage banks must replace the defaulted mortgage in the mortgage pool. In comparison to the US, defaults are rare. Denmark features full recourse, and banks are able to seize collateral relatively quickly. Banks perform initial screening of borrowers, but have no influence on interest rates, which, as described above, are determined by the market for mortgage bonds. All mortgage payments, including prepayments, are directed to covered bond investors, who assume prepayment risk. Mortgage banks receive a fee—roughly 70 basis points, on average—to compensate them for administrative costs and credit risk; the fee depends on LTV, but is otherwise independent of household characteristics. Borrowers' retail

banks work with the mortgage banks to arrange mortgage issuance and settle payments.

A unique feature of the Danish system is that borrowers have the option to prepay their loans at either face or market value. As a consequence, borrowers with fixed-rate mortgages may refinance to a more favorable rate if interest rates decline, but may also reduce their debt outstanding by repurchasing their mortgage at market value if interest rates increase.

2.2 Data sources

Mortgage data

We obtain mortgage data from the Danmarks Nationalbank, which in turn collects the data from mortgage banks through the Association of Danish Mortgage Banks (Realkreditrådet) and the Danish Mortgage Banks' Federation (Realkreditforeningen). The data provide a yearly snapshot of all outstanding mortgages from all mortgage banks in Denmark from 2008 to 2018.[2] We have personal identification numbers for borrowers, identification numbers for mortgages, and information on mortgage terms (principal, coupon, annual fees, maturity, loan-to-value, issue date, etc.).

Administrative household data

Our household data covers the universe of adult Danes from 2009 to 2019, and contains both demographic and economic information about this population. We derive this administrative data from several different registers made available through Statistics Denmark.

We obtain demographic information on mortgage borrowers from the Danish Civil Registration System (CPR Registeret). These records cover the entire Danish population and include each individual's personal identification number (CPR), as well as their name, gender, date of birth, and marital history. The records also contain a unique household identification number, as well as CPR numbers of each individual's spouse and any children in the household. We merge this information with records from the Danish ministry of Education (Undervisningsministeriet), which records each individual's highest level of education and any resulting professional qualifications.

We obtain income and wealth information from the Danish Tax Authority (SKAT). The data contains total and disaggregated income and wealth information by CPR numbers for

[2]The data use agreement requires us to merge data from all mortgage banks and does not allow us to study variation across banks. The Danish mortgage market is competitive and offers virtually homogeneous products, with minimal rate variation across banks. Consequently, we believe that bank-specific effects are not of first-order importance for our analysis.

the entire Danish population. SKAT receives this information directly from the relevant third-party sources. Employers supply statements of wages paid to their employees and financial institutions supply information to SKAT on their customers' deposits, interest paid (or received), security investments, and dividends. Because taxation in Denmark mainly occurs at the source level, income and wealth information are highly reliable.

One caveat is that some components of wealth are not recorded by SKAT. The Danish Tax Authority does not have information about individuals' holdings of unbanked cash, the value of their cars, debt owed to private individuals, defined-contribution pension savings, private businesses, or other informal wealth holdings. This leads some individuals to appear in the data with negative net financial wealth because we observe debts but not corresponding assets—this might occur, for example, if a person has borrowed to finance a new car.

Survey data

Statistics Denmark conducts a series of consumer surveys which elicit responses from households on a range of economic variables. The survey is administered on a monthly basis to a rolling panel of roughly 1,000 households. Households are surveyed on their financial situation including major purchases and savings, as well as their views on general economic circumstances including price trends, and unemployment. Some questions are administered quarterly, including queries about households' intention to buy a car, to purchase or build a home, or initiate home improvements. For a subset of mortgage borrowers, we link the administrative data to individual survey responses using the personal identification number of borrowers.

2.3 Sample

The data track roughly 1.3 million outstanding mortgage loans in each year between 2009 and 2018. This gives us more than 13 million loan×years representing roughly 3.25 million unique mortgages originated between 1989 and 2018. At the end of our sample, 47 percent of these loans were standard ARMs and 44 percent were standard FRMs.[3] We are able to match more than 99 percent of loan×years to households.[4]

Our primary focus is on mortgages originated during our sample window of 2009-2018. We

[3]The remaining loans are mainly two less common mortgage products: roughly 7 percent were capped ARMs—ARMs with pre-specified interest rate ceilings—and roughly 2 percent were variable rate with no initial fixed period.

[4]The minor merge error is due to two data issues: (i) a small fraction of loans are not associated with any personal identification number, and (ii) a small fraction of personal identification numbers are not linked to a household identifier.

consider only originations that match household data, and drop loans that first appear in the data after the stated issue year. This leaves a sample of just over 2 million unique originations. Panel A of Figure 1 shows the time-series of these originations, split between FRMs and all others (ARMs, capped ARMs and variable rate mortgages). The most active year for originations was 2012, with just under 260,000 new loans. The least active was 2011, with just over 135,000 new loans.

This full sample contains mortgages originated for multiple purposes, including new purchases, refinances, and non-concurrent additional liens (those taken after the initial mortgage). While the loan purpose is not directly recorded in the mortgage data, we are able to infer it using each household's mortgage history.[5] This definition requires at least one past year of data, so we are only able to identify the loan purpose between 2010-2018. This leaves us with roughly 1.8 million loan originations , of which 60% are refinances, 13% are non-concurrent additional liens, and 27% are new purchases.

In some of our analysis we focus on the subsample of new purchase mortgages taken by households against a single mortgaged property.[6] This set of criteria leaves us with roughly 420,000 originations, which we view as a particularly clean sample for considering the choice between fixed and adjustable rates. We further restrict the sample in some exercises to include only FRMs and ARMs with very short fixation periods (of 1 year or less). This subsample contains just under 300,000 loans. To provide more detail on the loans omitted due to these criteria, Panel A of Appendix Figure A.I shows the number of originations in our full sample by mortgage type and fixation period, while Panel B shows the fraction of loans that are classified as new purchases by type and fixation period.

Panel B of Figure 1 shows the time series of originations in this "new purchase" subsample. Given the omission of refinances in this sample, there is substantially less variation in originations over time. Additionally, because we omit ARMs with longer fixation periods (as well as variable rate mortgages and Capped ARMs) the share of FRMs in each year is substantially higher in each period.

[5]The mortgage purpose is defined as a new purchase if the household is not observed with a prior mortgage in the same municipality in our data. The mortgage purpose is defined as a refinance if the household is observed with a different mortgage in the same municipality that terminates in the previous year. The mortgage purpose is defined as a non-concurrent additional lien if the household has an additional active mortgage in the same municipality that was originated in a previous year. This categorization may incorrectly assign households who purchase a new home in the same municipality as refinances, but provides a clean sample of new purchases.

[6]To identify a single mortgaged property, we require households to have mortgages in at most one municipality, and that the sum of the loan-to-value ratios of these mortgages be less than 100. This criteria may fail to screen out a handful of households with relatively small mortgages on multiple properties in the same municipality.

2.4 Summary statistics

Panel A of Table 1 shows summary statistics for the full sample of originations in our data. The average loan is approximately 1.3 million Danish Krone (DKK), or more than $210,000. The largest loans are well over 4 million DKK. The average interest rate is just below 2 percent, although a small portion of the sample has negative rates. Roughly half of originations are FRMs, and 45 percent are traditional ARMs. 55 percent of all loans are Interest Only (IO), which offer the borrower the option to forgo any amortization payments for a 10 year period.[7]

Panel B of Table 1 shows summary statistics for our subsample of mortgages for new home purchases. These loans are slightly larger on average than the full sample, with slightly higher interest rates and Loan-to-Value (LTV) ratios. Because we drop ARMs with long initial fixation periods, the proportion of FRMs is much higher in this sample at 78 percent.

Table 2 shows summary statistics for the households matched to these loans. Panel A again shows the full sample. The average education level for these households is high, at more than 15 years, and households have less than one child on average at the time of origination. Median housing assets are 1.76 million DKK, and the median household has no stocks or bonds, but does hold bank deposits. Panel B shows summary statistics for households tied to our new purchase subsample. These households are younger on average, with lower incomes, fewer assets, and less debt.

3 Evidence on Mortgage Choice in Danish Data

We begin our analysis with a series of empirical observations on the cross-section of mortgage choice. Our organization of these findings is guided by the predictions of earlier models of mortgage choice (e.g., Campbell and Cocco, 2003). We first discuss facts in the data that align with these predictions, followed by findings that are difficult to square with this theoretical literature. We conclude with a third set of facts which suggest that a richer model—which accounts for the effects of heterogeneity in wealth and housing on mortgage choice—is necessary to capture the variation observed in the data. This motivates the set up of our model in the subsequent section.

[7]The IO share is higher among ARMs, around 80%, and lower among FRMs, around 40%. We do not explore this fact in this version of the paper, but it deserves further analysis.

3.1 Alignment with theory: moving and inflation expectations

Existing models of mortgage choice predict several observations which are clearly verified in Danish data. One standard prediction of these models, including Campbell and Cocco (2003), is that households who expect to move in the near future will be more likely to choose ARMs; this has also been confirmed in early empirical work on mortgage choice (Shilling, Dhillon, and Sirmans, 1987). The logic of this prediction is straightforward: A household that expects to move in the near future values the lower interest rate provided by an ARM today over the nominal protection offered by an FRM. The household can hedge exposure to interest rate increases using future mortgage choice decisions if and when they take on a new mortgage in their destination.

Fact 1: ARM choice predicts moving

Figure 2 shows that this prediction holds in the Danish data. Realized moving probabilities are strongly positively correlated with ARM choice. Compared to borrowers with FRMs, borrowers with ARMs are roughly 20% more likely to move within 3 years of origination, and almost 40% more likely to move within 5 years. In other words, borrowers with ARMs are more likely to move in the short term. This empirical finding is consistent with households having information regarding their own moving probabilities, and acting on this information when choosing a mortgage.

Fact 2: High inflation expectations predict FRM choice

Another standard feature of models following Campbell and Cocco (2003) is the connection between inflation and ARM choice. An ARM provides an inflation hedge, in the sense that its real capital value is virtually invariant to inflation. On the other hand, without a prepayment option, a nominal FRM is highly exposed to the risk of inflation: its real capital value varies with inflation—this is pernicious when there is deflation which causes the real value of FRM repayments to rise, but beneficial in periods of positive inflation. The easy availability of refinancing in Denmark allows borrowers some ability to avoid this downside risk, but increases the interest rate spread between FRMs and ARMs, making FRMs expensive if interest rates are stable.

A natural prediction of the theory is that borrowers who expect inflation to rise are more likely to choose FRMs. These borrowers should be willing to incur a higher interest rate up front, expecting a benefit if inflation increases and the real value of payments fall. Figure 3 shows that this prediction holds in the Danish data. Borrowers that expect higher inflation are more likely to choose FRMs and less likely to choose ARMs. The red bars in this figure show survey responses for the set of borrowers that are included in both the consumer confidence survey conducted by Statistics Denmark and our full sample of originations.

Specifically, we consider responses to the question "How do you think prices will develop over the next 12 months?" As Figure 3 shows, borrowers who expect prices to rise more slowly, remain unchanged, or fall slightly relative to the past year are more likely to choose ARMs than those who expect prices to rise faster or to rise at the same rate. The blue bars show the fraction of borrowers providing each response.

3.2 Contrast with the literature: income growth and mortgage principal

While mortgage choice in Denmark aligns with the predictions of the literature in several dimensions, other observations from the data are more puzzling. The literature suggests that factors that lead borrowers to weigh current interest costs more than longer horizon considerations should push borrowers towards ARMs, which bear lower interest costs (see, e.g., Badarinza, Campbell, and Ramadorai, (2021)). One such factor is borrowing constraints, which can bind for households with relatively low current incomes and lead them to choose ARMs despite the risk that nominal payments later rise. These anticipated risks of rising future payments will be smaller for current constrained households that expect their incomes to grow in the future, leading to the prediction that such households will prefer ARMs over FRMs. While this seems intuitive, two features of the data stand in direct contrast to this prediction.

Fact 3: Youth and income growth do not predict ARM choice

While we do not observe household income expectations, we do observe realized income growth. If borrowers have rational expectations about their own incomes, realized income growth will be informative about ARM choice. However, in the data, there is no evidence of a positive relationship between ARM choice and realized future income growth. Figure 4 shows histograms of 1, 3 and 5 year income growth rates for FRM borrowers and ARM borrowers in our full sample of originations (patterns are similar when restricting to the new purchase subsample). As these figures show, the distribution of income is, if anything, slightly right shifted for borrowers with FRMs relative to those with ARMs. Those with FRMs experience slightly higher income growth on average. This stands in contrast to models that suggest that high expected income growth correlates positively with ARM choice.

The patterns with respect to the age distribution are similar. Younger borrowers should, on average, expect faster income growth than older borrowers; yet we observe a distinct upward trend in ARM preference by age, shown in Figure 5. This pattern is evident in the full sample of originations (shown in Panel (A)) and is even more pronounced in the new purchase subsample (shown in Panel (B)).

Fact 4: Borrowers with high mortgage principal prefer ARMs

Another contrast with the literature arises when considering the relationship between mortgage principal and ARM choice. A key risk that constrained borrowers face with an ARM is the possibility that increases in interest rates will lead to higher nominal interest payments potentially resulting in reduced consumption in the short term. As Campbell and Cocco (2003) note, this suggests that borrowers with large mortgages relative to their incomes should be hesitant to take on an ARM.

Figure 6 shows a nearly opposite pattern. Borrowers with the largest mortgages in terms of principal are substantially more likely to choose ARMs over FRMs. Panels (a) and (b) of this figure show mortgage choice across the distribution of mortgage principal in red (with the distribution of originations shown in blue). Panel (a) uses the full sample of originations, and shows something of of a u-shape. The ARM Share is high for borrowers with the smallest mortgages, lower for those in the middle of the distribution, and high again for those with the largest mortgages. Excluding refinances, the relationship is much closer to monotonic. This is evident in panel (b), which considers only the new purchase subsample.

Of course, Figure 6 shows the level of principal rather than the ratio of principal to income, and does not account for other underlying factors that might correlate with choosing a large mortgage. To address this, we consider a saturated regression model that considers the ratio of principal-to-income, and conditions on various other household variables. Specifically, for mortgage i we estimate the following model:

$$ARM_i = \alpha + \gamma_{MDebt(i)} + \delta_{ODebt(i)} + \eta_{HAsset(i)} + \theta_{FAsset(i)} + \kappa_{age(i)} + \lambda_{KOM(i)} + \mu_{month} + \varepsilon_i. \quad (1)$$

Here $\gamma_{MDebt(i)}$ indicates dummies for deciles of mortgage principal relative to income for the household with mortgage i, $\delta_{ODebt(i)}$ indicates dummies for deciles of other debt relative to income, $\eta_{HAsset(i)}$ indicates dummies for deciles of housing assets relative to income and $\theta_{FAsset(i)}$ indicates dummies for deciles of financial assets relative to income. $\kappa_{age(i)}$, $\lambda_{KOM(i)}$, and μ_{month} represent dummies for age, geographic district, and origination month, respectively. ARM is an indicator equal to one if the mortgage is an ARM.

In line with our earlier evidence, we find here that the ratio of mortgage principal to income is strongly positively correlated with ARM choice. The coefficients on deciles of the ratio increase in magnitude from the 2nd through the 10th deciles. From a risk perspective, this is somewhat puzzling, as these borrowers are potentially exposed to large swings in monthly mortgage payments relative to income. However, one plausible explanation is that the lower monthly payments associated with ARMs are necessary to satisfy lenders' implicit or explicit payment-to-income requirements.

3.3 Beyond the literature: new puzzles

Two other facts have not been noted in the previous literature and deserve further investigation.

Fact 5: a U Shape in ARM choice by wealth

We find a pronounced U-shaped relationship between ARM choice and wealth. Put simply, borrowers at both the highest and lowest ends of the wealth distribution are more likely to choose ARMs, while borrowers at the center of the wealth distribution of mortgage borrowers are more likely to choose FRMs.

Figure 8 plots the ARM share for each decile of net wealth in both our full sample of originations (Panel A) and in our new purchase subsample (Panel B). We define net wealth as the difference between (observable) total assets and total debts including housing and financial assets as well as mortgage and non-mortgage debt. Across both samples there is a pronounced U shape. In the sample of all originations, more than 50 percent of loans are ARMs in both the top and bottom deciles of net wealth. In the 5th and 6th deciles the share is closer to 40 percent. A roughly similar pattern is evident in the new purchase subsample, although there is a particularly high share in the wealthiest decile.[8]

The saturated regression model shown in Figure 7 reinforces this finding. Panel (d) shows a large positive coefficient on the top decile of financial assets, relative to income, suggesting that those with substantial assets are significantly more likely to choose an ARM, holding the relative position of the rest of the balance sheet fixed. A shape is also evident here, those in the lowest deciles are also relatively less likely to choose an ARM.

The propensity of borrowers at the low end of the wealth distribution to choose ARMs is in line with standard models, which suggests that constrained borrowers (with a particularly high marginal utility of consumption) may prefer the lower monthly payments associated with ARMs. The tendency of borrowers at the top end of the distribution to choose ARMs is less well established. One potential explanation is that it reflects wealthy borrowers leveraging housing to invest in other assets.

Fact 6: unobserved influences on mortgage choice

A final fact worth noting is that even our saturated model that includes many observable determinants of mortgage choice has relatively low explanatory power. The full regression,

[8]Note that the ARM share is much lower across all deciles in our new purchase subsample. This is a mechanical feature of our sample selection criteria, which eliminates all ARMs with a fixation period above 1 year.

including all household balance sheet variables and fixed effects for borrower age, the month of mortgage origination, and the district where the property is located, has an R^2 statistic of 14%. The balance sheet variables alone produce an R^2 statistic of 3.6%, origination month dummies alone deliver an R^2 statistic of 8.6%, district dummies alone deliver 2.3%, and age dummies alone deliver 1.7%. Thus there are important influences on mortgage choice that we do not measure. The formal modeling effort that we now undertake is intended to explain demographic and balance sheet influences on mortgage choice, but it cannot illuminate this "dark matter".

4 A Model of Mortgage Choice

To begin to interpret the empirical evidence, we build a model that incorporates many of the relevant economic considerations that should affect mortgage choice. The model extends Campbell and Cocco (2003, 2015) and Campbell, Clara, and Cocco (2021) to fit specific features of the Danish economy and mortgage system.

4.1 Preferences and initial choices

We model the choices of households that are heterogeneous along several dimensions. To simplify the notation in the description of the model below, we drop the i subscript denoting the household. We use the subscript t, for $t = 1, ..., T$, to denote the model period (or the age the household).

In each period, the household derives utility from housing (denoted H_t) and non-durable consumption (C_t). We model choices for T periods, but the household derives utility from terminal wealth (W_{T+1}), which can be interpreted as the remaining lifetime utility from reaching age $T + 1$ with a given wealth level. Household preferences are:

$$\mathrm{E}_1 \sum_{t=1}^{T} \beta^{t-1} u(C_t, H_t) + \beta^T v(W_{T+1}). \tag{2}$$

In periods prior to the terminal date, per-period utility is a power function of a Cobb-Douglas aggregation of consumption spending and housing:

$$u(C_t, H_t) = \frac{(C_t^{1-\theta} H_t^{\theta})^{1-\gamma}}{1-\gamma}, \tag{3}$$

where γ is the coefficient of relative risk aversion. The utility of terminal wealth is given by:

$$v(W_{T+1}) = b\frac{W_{T+1}^{1-\gamma}}{1-\gamma}, \tag{4}$$

where b captures the preference for terminal wealth.

At the initial date the household is endowed with a given amount of initial wealth or cash-on-hand (X_1) that includes previously accumulated financial savings (W_1) and initial income (Y_1):

$$X_1 = W_1 + Y_1 \tag{5}$$

The household must decide the size of the house to purchase (H_1), the amount to put down as deposit (or equivalently the amount to borrow, denoted D_1), the type of mortgage that it will use (ARM or FRM), non-durable consumption (C_1) and how to invest any remaining financial savings that are not used for the deposit. This is a large set of initial choices that allows us to capture several dimensions of households' decisions and the impact of heterogeneity on those decisions, to help explain the rich set of empirical facts uncovered in the previous section.

4.2 Stochastic processes

Before we describe household choices at intermediate dates, we first describe the stochastic processes in the model.

House prices

Without loss of generality, we normalize the initial price of housing, i.e., P_1^H to one. In periods subsequent to the initial date, house prices are stochastic and follow a random walk with drift. We use lower case letters to denote the natural log of variables, so $p_t^H \equiv \log(P_t^H)$. The expression for the change in period t log real price of housing is:

$$\Delta p_t^H = \mu_H + \varepsilon_t \tag{6}$$

where ε_t is a normally distributed shock with mean zero and standard deviation σ_ε.

Income

Household income is stochastic. The logarithm of income $y_t \equiv \log(Y_t)$ follows the process:

$$y_t = f(t) + \epsilon_t + q_t \tag{7}$$

where $f(t)$ is a deterministic function of age and other individual characteristics, ϵ_t is a temporary income shock distributed as $N(0, \sigma_\epsilon)$ and q_t is permanent income:

$$q_t = q_{t-1} + \nu_t \tag{8}$$

where ν_t is a normally distributed shock with mean zero and standard deviation σ_ν. We allow for income shocks to potentially be correlated with house price innovations.

Financial assets

The risk-free real interest rate is stochastic. Let $r_{1t} = \log(1 + R_{1t})$ denote the log of the gross real short rate; it follows an $AR(1)$ process:

$$r_{1t} = \mu_r(1 - \phi) + \phi r_{1,t-1} + \iota_t \tag{9}$$

where ι_t is a normally distributed shock with mean zero and standard deviation σ_ι.

Households with positive financial savings can invest their savings at the risk-free rate or in a risky financial asset that we interpret as a position in equities (stocks). The log gross return on stocks $r_t^S = \log(1 + R_t^S)$ is given by:

$$r_t^S = r_{1t} + \mu_S + \zeta_t \tag{10}$$

where μ_S is the (assumed constant) equity premium and ζ_t is a normally distributed shock with mean zero and standard deviation σ_ζ, uncorrelated with interest rates.

4.3 Term structure of interest rates

We assume that the log expectations hypothesis holds. That is, we assume that the log yield on a long-term n-period real bond, $r_{nt} = log(1 + R_{nt})$, is equal to the expected sum of successive log yields on one-period real bonds which are rolled over for n periods plus a constant term premium, ψ, i.e.:

$$r_{nt} = (1/n) \sum_{j=0}^{n-1} E_t[r_{1,t+j}] + \psi. \tag{11}$$

This term structure implies that homeowners cannot reduce their average borrowing costs by trying to time the bond market.

4.4 Mortgage contracts

At the initial date, the household must decide how much of their previously accumulated savings to use for the house purchase; the remainder of the purchase price is financed using a mortgage of amount D_1. To match with the Danish institutional environment, the model features both loan-to-value (LTV) and mortgage payment-to-income (PTI) constraints that limit the maximum amount that the household can borrow. That is, D_1 must be chosen such that:

$$LTV_1 = \frac{D_1}{P_1 H_1} \leq \overline{LTV} \tag{12}$$

$$PTI_1 = \frac{M_1}{Y_1} \leq \overline{PTI} \tag{13}$$

where M_1 denotes initial mortgage payments, which depend on the amount borrowed, the type of mortgage contract chosen and the interest rate.

Fixed rate mortgages

The interest rate on the fixed rate loan is equal to the interest rate on a T period bond plus a premium θ^{FRM}:

$$R_{T,1}^{FRM} = R_{T,1} + \theta^{FRM}. \tag{14}$$

For a fixed rate mortgage (FRM) of amount D_1 with interest rate $R_{T,1}^{FRM}$ and maturity T taken at the initial date, per-period mortgage payments are given by:

$$M^{FRM} = \frac{D_1}{\sum_{j=1}^{T}(1 + R_{T,1}^{FRM})^{-j}} \tag{15}$$

For an FRM the required mortgage payments are fixed at the initial date and assumed constant for the full term, unless the household refinances. In each period t, the household may decide to refinance the loan and take out a new FRM with either the same amount or a different amount than the current mortgage balance. When the household refinances, the mortgage rate may be different than the contracted rate at the original date, and we denote it by $R_{T,t}^{FRM}$. This rate can be used to calculate the present value (PV) of the stream of mortgage payments left in the original loan:

$$PV_t = M^{FRM} \sum_{j=t}^{T}(1 + R_{T,t}^{FRM})^{-j} \tag{16}$$

We let D_t^- denote the principal amount of the original loan still outstanding at time t prior to the refinancing. For congruence with the Danish institutional environment, the amount that is due to the lender is then:

$$\text{Loan repayment}_t = MIN[D_t^-, PV_t] \tag{17}$$

Put differently, the household repays the minimum of the outstanding principal and the present value of the stream of outstanding mortgage payments. When refinancing rates are higher than rates at origination, the present value of the stream of payments is lower than the outstanding principal. In the US, in a comparable scenario, the amount payable would still be the outstanding loan amount, which reduces incentives for households to refinance. However, in Denmark, the gain accrues to borrowers, who can advantageously prepay at market value if rates rise, and at face value if rates fall.

If we let D_t^+ denote the amount of the refinanced loan, equity extraction is given by:

$$\text{Extraction}_t = D_t^+ - MIN[D_t^-, PV_t]. \tag{18}$$

Another feature of the Danish system is that borrowers are always able to refinance, even with negative home equity, provided that there is no equity extraction. However, when equity

is extracted, both LTV and PTI constraints must be satisfied. The mortgage payments of the refinanced loan are calculated using the new loan amount, the refinancing rate, and the annuity formula. In addition, refinancing borrowers must pay a refinancing cost.

In Denmark mortgage loans are full recourse. In case of default, lenders can seize the collateral, and have recourse to borrowers' future labor income which eliminates incentives for strategic default. Because of this, and in order to simplify the model solution, we do not model default explicitly. In case borrowers cannot meet mortgage payments, we assume that they receive a minimum level of housing and non-durable consumption in each period for the remaining horizon.

Adjustable rate mortgages

If at the initial date the household chooses an adjustable rate mortgage (ARM), then the required mortgage payments fluctuate with the level of interest rates. The period t payment due on the mortgage is given by:

$$M_t^{ARM} = R_t^{ARM} D_t + \Delta D_{t+1}, \tag{19}$$

where D_t is the principal amount outstanding on the loan at the beginning of period t before any mortgage payments are made in that period and ΔD_{t+1} is the loan principal repayment due in period t. In order to save on state variables, we assume that the principal repayment equals that previously calculated for the FRM.

The interest rate on the ARM is equal to the short rate plus a premium θ^{ARM}:

$$R_t^{ARM} = R_{1t} + \theta^{ARM}. \tag{20}$$

In each period, the household can refinance the loan and extract equity (in which case the LTV and PTI constraints apply) or use accumulated financial wealth to repay the mortgage. Loan refinancing is costly, and we provide details on how we calibrate these costs and other parameters below.

4.5 Budget constraint, choice and state variables

The budget constraint for periods $t > 1$ in which the loan is not refinanced is given by:

$$X_{t+1} = (X_t - C_t)[1 + [(1 - \alpha_t)R_{1t} + \alpha_t R_{t+1}^S](1 - \tau)] + (1 - \tau)Y_{t+1} - M_{t+1}, \tag{21}$$

where α_t is the portfolio share invested in stocks τ is the tax rate on capital gains and income. In periods when the loan is refinanced:

$$X_{t+1} = (X_t - C_t - \text{Loan repayment}_t + D_t^+ - \text{refcost})[1 + [(1-\alpha_t)R_{1t} + \alpha_t R_t^S](1-\tau)] + (1-\tau)Y_{t+1} - M_{t+1}, \tag{22}$$

where recall D_t^+ is the amount of the refinanced loan and refcost is the cost of refinancing. At the initial date the household has previously accumulated financial assets and initial income (denoted X_0) that together with a loan are used to finance the purchase of the house:

$$X_1 = X_0 - P_1^H H_1 + D_1. \tag{23}$$

In order to simplify the analysis, we assume that the house size chosen by the household at the initial date remains fixed throughout. This means that in periods $t > 1$ the choice variables are: (i) non-durable consumption (C_t); (ii) choice of financial savings vehicle (stocks or one-period bonds); (iii) whether to use previously accumulated financial savings to pre-pay the mortgage; (iv) for the FRM, whether to refinance into a new FRM loan.

For each mortgage contract, the state variables of the problem are: (i) time; (ii) cash-on-hand; (iii) permanent income; (iv) house prices; (iv) interest rate; (v) interest rate at mortgage origination; (vi) house size; and (vii) amount borrowed at mortgage origination.

4.6 Parameterization

We use our Danish sample to parameterize the model, and show the values of our key parameters in Table 3. Although each model period corresponds to two years, we report parameters in the table on an annualized basis. Mortgages have a maturity of 30 years, corresponding to 15 periods in the model.

Time and preference parameters

We choose standard values for basic preference parameters. We set the annual discount rate $\beta = 0.99$ and the coefficient of risk aversion $\gamma = 2$. We set θ, the Cobb-Douglas parameter that governs the tradeoff between consumption and housing, to 0.2. The preference for terminal wealth, b, is set to 25.

Policy constraints and taxes

We choose features of the policy environment to match the Danish context. The minimum down payment is set to 20%. The income tax rate is set to 42%, which is the average realized rate across borrowers in our clean new purchase sample.[9]

Income and wealth

Income and wealth parameters are chosen to match the Danish data. To determine the initial income and wealth level we run the following regression on all households in our clean sample:

$$\mathrm{y}_i = \alpha_{married(i)} + \gamma_{Age(i)} + \delta_{Education(i)} + \eta_{HHSize(i)} + \varepsilon_i, \tag{24}$$

and predict income (excluding capital income) or wealth (excluding pension wealth) for a household with the following characteristics: (i) married, (ii) the oldest household member is 35 years old, (iii) 16 years of education, (iv) 3 total household members. This gives a value of 663,000 DKK for income. We similarly estimate wealth at retirement by setting the age of the oldest household member to 62.

To calculate the deterministic growth rate of income over the lifecycle, we consider all households that are homeowners at some-point in our sample period (2009-2018). We then drop years prior to first observing housing wealth, and drop any observations in which the age of the oldest household member is (i) greater than 50 or (ii) less than 30. We estimate the following regression for household i in year t:

$$\log(\text{Income})_{it} = \beta \text{Age}_{it} + \alpha_{married(it)} + \delta_{Education(it)} + \eta_{HHSize(it)} + \theta_i + \varepsilon_{it} \tag{25}$$

This delivers an estimate $\hat{\beta} = 0.011$.

To estimate the variance of the temporary and permanent innovations in income, we follow the procedure of Carroll and Samwick (1997), after residualizing with respect to age, education, marital status, household size, and location, and winsorizing at the 5% level. This gives us estimates of $\hat{\sigma}_\eta = 0.11$ and $\hat{\sigma}_\varepsilon = 0.14$.

[9]The clean sample includes borrowers (i) originating new mortgages between 2009-2018 (ii) with FRMs or short fixation period (1 year or less) ARMs (iii) that own a single property in a municipality.

House prices, stock returns, and mortgage premia

Following Calvet et al (2023) who study comparable Swedish data, we set the standard deviation of excess stock returns at 13.3%. In this version of the paper we assume a low equity premium of 2.44% implying a Sharpe ratio of only 0.17, but we plan to explore the implications of alternative Sharpe ratio assumptions in future work.

Using data on an aggregate Danish house price index from 1979-2018, we estimate the mean and standard deviation of log house price growth as 1.27% with a standard deviation of 9.1%.

In the mortgage market, we set the annual FRM premium to be 2.44% and the ARM premium to be 1%.

FRM refinancing costs

Following Andersen et al. (2020), we establish from a sample of price lists obtained from Danish mortgage banks, and from conversations with these banks, that the total DKK monetary cost of refinancing is well approximated by

$$\kappa(m_{i,t}) = 3000 + \max(0.002m_{i,t}, 4000) + 0.001m_{i,t}. \tag{26}$$

The first two terms correspond to bank handling fees in the range DKK $3,000 - 7,000$ (about US\$ $450 - 1,050$) and the third term represents the cost incurred to trade mortgage bonds to implement the refinancing. For extremely large mortgages, the third term may not increase directly with the size of the new mortgage (as there are significant incentives for wealthy households to shop, and variation across banks in their "capping" policies) so we additionally winsorize $\kappa(m_{i,t})$ at the 99th percentile, a value just below DKK 10,000 (about \$1,500). This additional winsorization does not make a material difference to our results.

Correlations

We set the correlation between income shocks and interest rates to zero. We also assume that temporary income shocks have a zero correlation with house prices, but we allow permanent income shocks to have a nonzero correlation with house prices. A preliminary empirical analysis delivers a very low correlation estimate of 0.016 which we use in this version of the paper. In future drafts we plan to refine these estimates and conduct a robustness analysis of the effect of alternative correlation assumptions on our results.

4.7 Model output

As a preliminary indication of the value of the model we have described, Figure 9 presents an analysis of the welfare gain to households in the first period of the model from choosing an ARM relative to a FRM. We consider households at various wealth levels corresponding to different deciles of the wealth-income ratio in Danish data. Households at the left of the figure have low financial assets and tend to be borrowing-constrained, while households at the right have high levels of financial assets.

Each line in the figure shows the welfare gain from an ARM, in lifetime consumption-equivalent units, at a different level of the interest rate. The green line corresponds to a low real interest rate of -2% and a FRM-ARM spread of 4%. When ARMs have such low current interest rates, all households strongly prefer ARMs but particularly those with lower levels of wealth. The orange line corresponds to a real interest rate of 1.5% and a FRM-ARM spread of 1.5%, leading to a modest preference for ARMs throughout the wealth distribution. The blue line corresponds to a high real interest rate of 5% and a negative FRM-ARM spread of -1%. At this level of interest rates, constrained households prefer FRMs to keep their current interest costs low, but wealthy households continue to prefer ARMs.

The figure shows that the motivation for ARM choice varies with wealth. Low-wealth households are motivated primarily by the current spreads between alternative mortgage rates, while wealthy households have a more stable ARM demand that varies less with the current short-term interest rate.

5 Conclusion

In this paper we have begun the challenging task of explaining the decisions that people make when choosing between ARMs and FRMs. We have explored these decisions in Denmark, where both ARMs and FRMs are common and where excellent administrative data make it possible to characterize the demographic and balance-sheet characteristics of mortgage borrowers.

Even with the rich data available in the Danish context, mortgage choice is hard to predict from observable household characteristics. A saturated regression including many variables and allowing them to predict mortgage choice nonlinearly has an explanatory power for the ARM-FRM decision of only 14%, much of which comes from time fixed effects. An important agenda for future research is to generate new data, for example on beliefs or social connections, that may shed light on this mysterious variation in ARM-FRM preference.

However we do find several patterns relating mortgage choice to economic observables that should be explicable from standard economic models. Some of these patterns are straightforwardly consistent with existing theory, for example the tendency for ARMs to be preferred by people who expect to move relatively soon and who therefore particularly value a low current interest rate.

Other patterns are new and in this paper we have highlighted the fact that ARMs are preferred by people at both ends of the distribution of wealth-income ratios. People with low financial wealth after buying their home, who are plausibly borrowing-constrained, prefer ARMs; but so do people with particularly high financial wealth. This pattern is reminiscent of the well known phenomenon in the US mortgage market that the ARM share is higher in subprime and jumbo mortgage loans, and lower in prime conforming loans. That phenomenon is sometimes attributed to an implicit subsidy to FRMs from the securitization of prime conforming loans by the US government mortgage agencies, but this cannot be the explanation in Denmark.

We have built a model of life-cycle mortgage and portfolio choice that we hope will shed light on the relation between financial wealth and ARM preference. We have shown that borrowing constraints are associated with ARM demand that varies strongly with the level of interest rates, or equivalently with the spread between initial ARM and FRM rates. However wealthy households have a relatively stable preference for ARMs. In future versions of this paper we hope to explore more systematically the ability of our model to match the main cross-sectional and time-series patterns in Danish mortgage choice.

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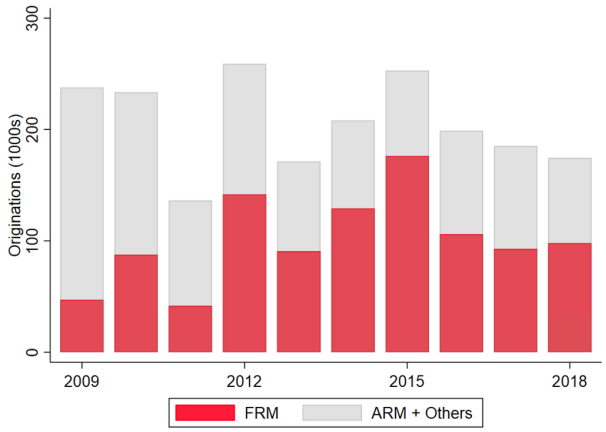
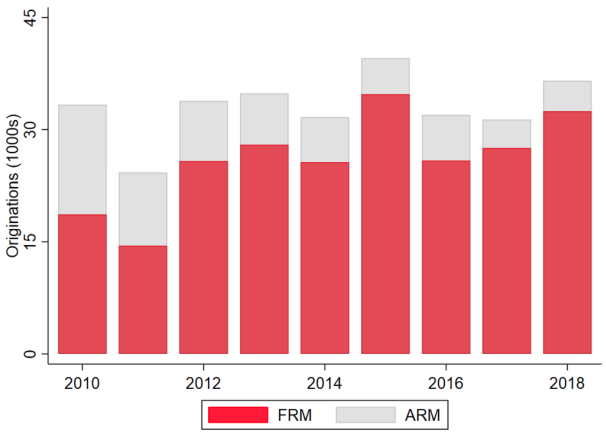
Figure 1: Mortgage Originations Over Time

Panel A: All Originations



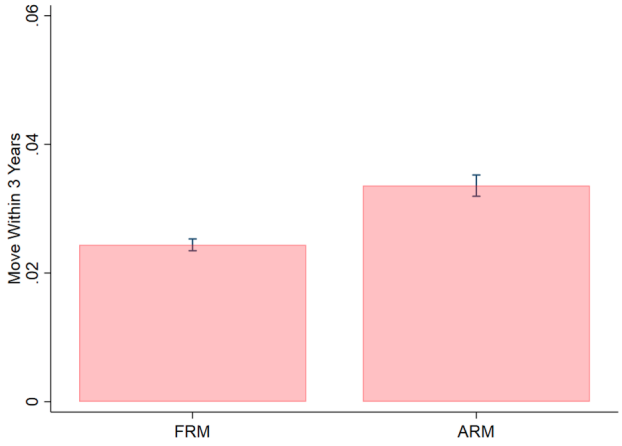
Panel B: New Purchase Subsample



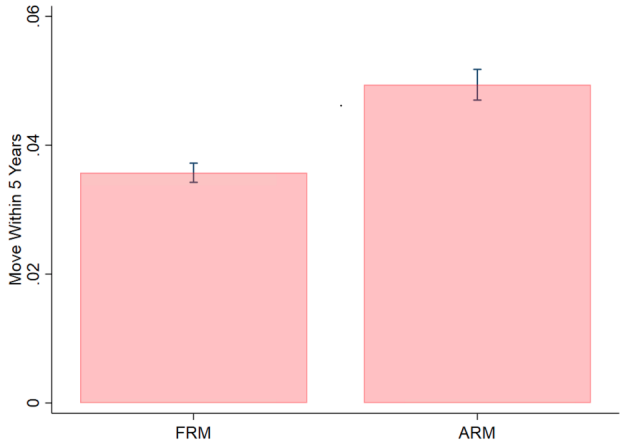
Notes: Panel A shows the number of new mortgage originations in Denmark by year in our matched household sample covering 2009-2018. Red bars show FRMs, grey bars show ARMs and all other mortgage types. Panel B shows the number of new mortgage originations in our subsample of new purchases, which covers 2010-2018 and includes only ARMs with very short fixation periods (1 year or less) and 30 year FRMs.

Figure 2: ARM Choice Predicts Moving

Panel A: Moving Within 3 Years

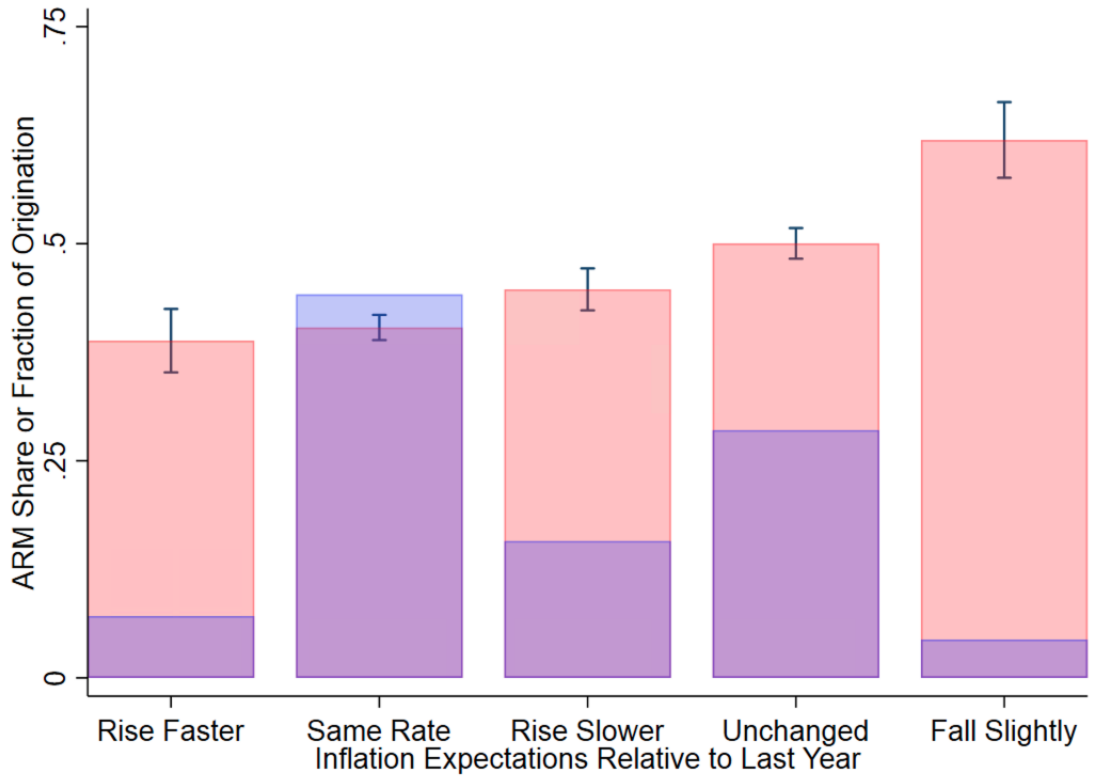


Panel B: Moving Within 5 Years



Notes: These figures show average realized moving rates among borrowers in our full sample of new originations with either FRMs or ARMs. Panel A shows moving within 3 years, while panel B shows moving within 5 years. Error bars show 95 percent confidence intervals.

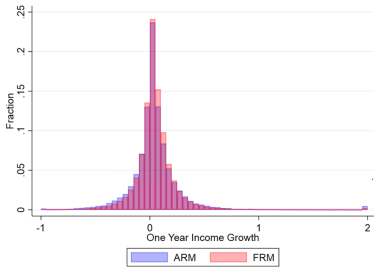
Figure 3: High Inflation Expectations Predict FRM Choice



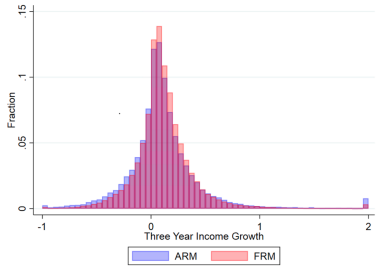
Notes: Red bars show the ARM share for mortgage borrowers matched to Statistics Denmark's consumer survey for each possible answer to the question "How do you think prices will develop in the next 12 months?" Error bars represent 95 percent confidence intervals. Blue bars show the fraction of respondents providing each response.

Figure 4: ARM Choice Does Not Predict Income Growth

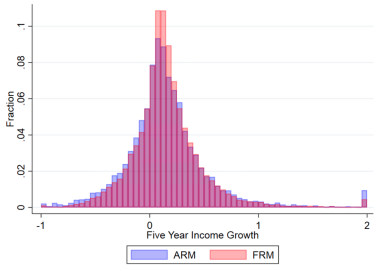
Panel A: One Year



Panel B: Three Year



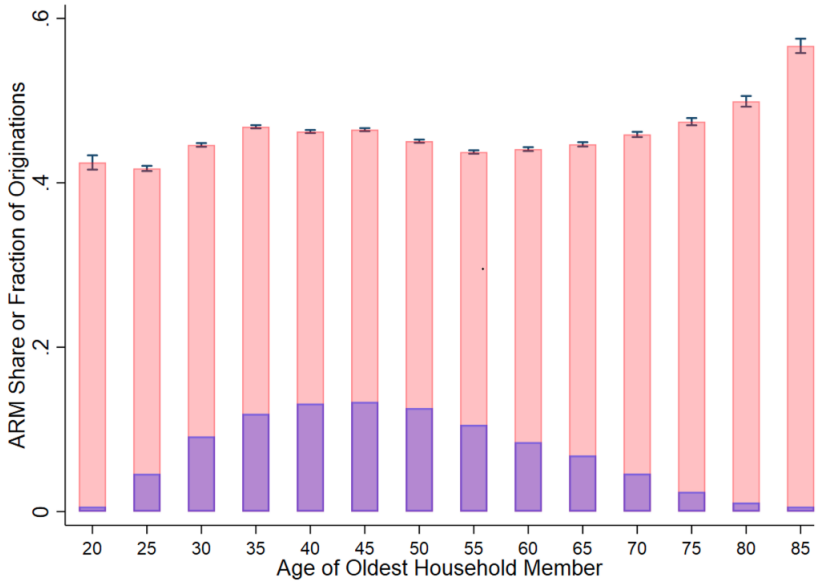
Panel C: Five Year



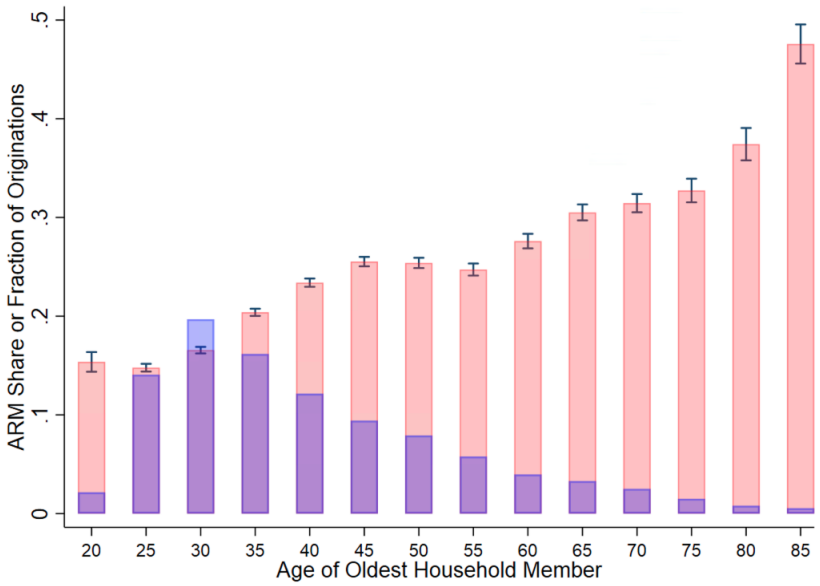
Notes: Histograms of the one year, three year, and five year income growth rate for ARMs and FRMs in our full sample of originations.

Figure 5: ARM Share Increasing in Age

Panel A: All Originations



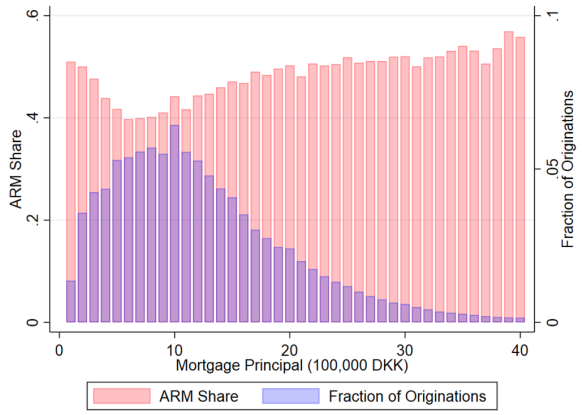
Panel B: New Purchase Subsample



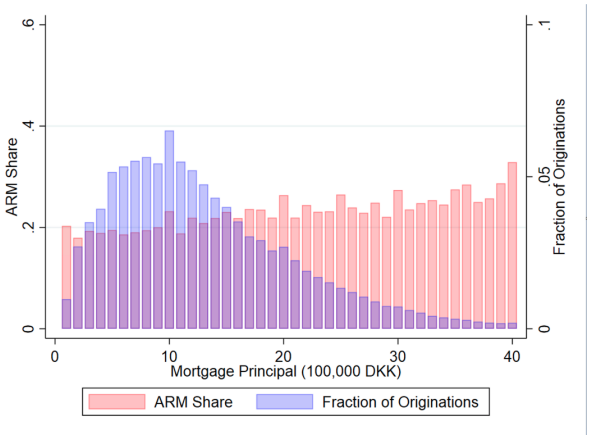
Notes: ARM share in five year age bins for the full sample (Panel A) and the new purchase subsample (Panel B). Error bars represent 95 percent confidence intervals.

Figure 6: Mortgage Principal and ARM Choice

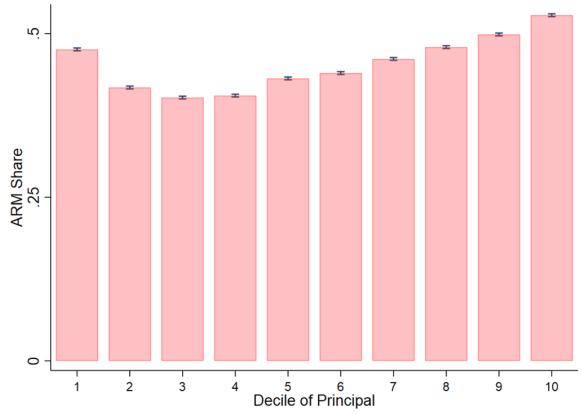
(a) All Originations



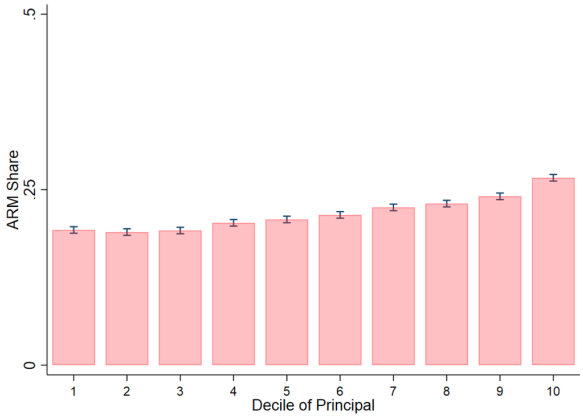
(b) New Purchase Subsample



(c) All Originations



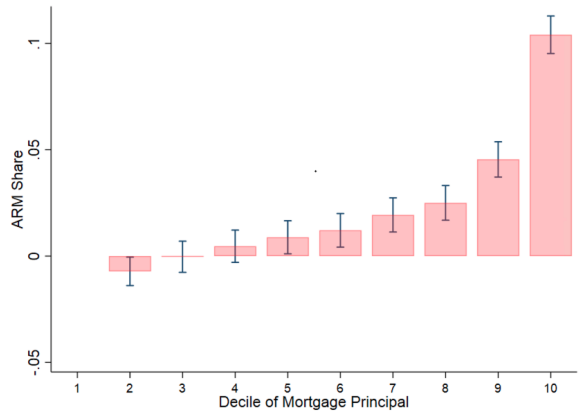
(d) New Purchase Subsample



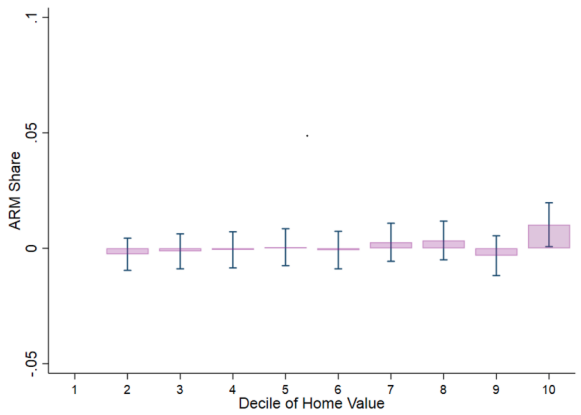
Notes: ARM choice by mortgage principal. Panels (a) and (b) show share of ARMs by mortgage principal rounded to the nearest 100,000 DKK, as well as the fraction of originations in each 100,000 DKK bin. Panel (a) shows the full sample while panel (b) shows the new purchase subsample. Panels (c) and (d) show the ARM share by decile of mortgage principal in the full sample and new purchase subsample, respectively. Error bars represent 95 percent confidence intervals.

Figure 7: A Saturated Regression Model

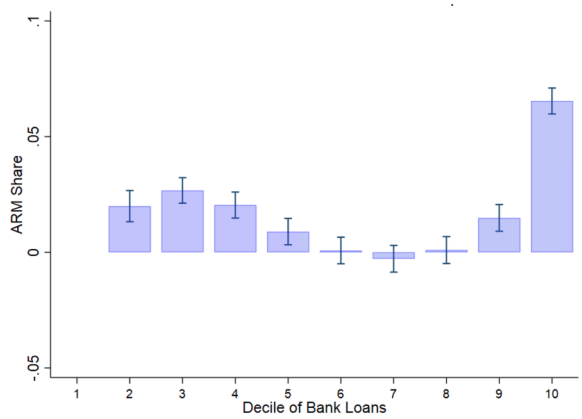
(a) Mortgage Principal



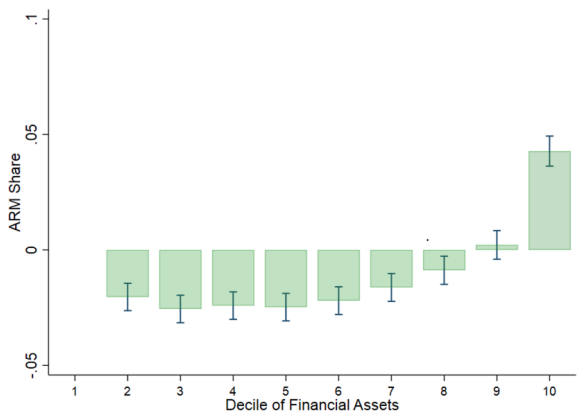
(b) Home Value



(c) Bank Loans



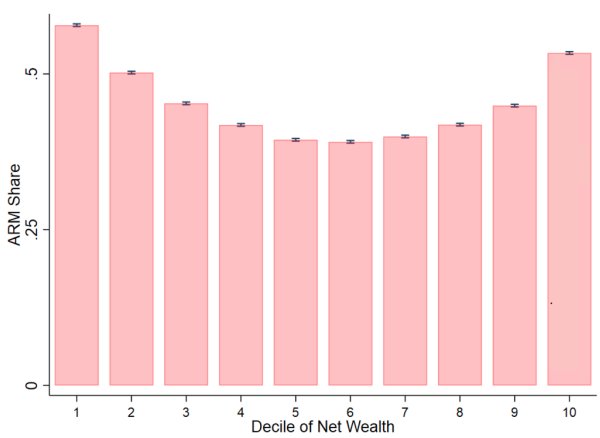
(d) Financial Assets



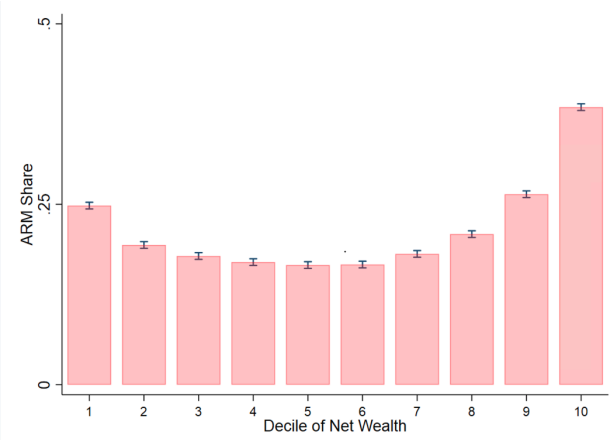
Notes: Coefficients from a regression of a binary indicator for ARM choice on dummy variables for deciles of mortgage principal to income, other debt to income, housing assets to income, financial assets to income, age, origination year and district. Error bars represent 95 percent confidence intervals.

Figure 8: Adjustable Rate Mortgage Share by Wealth

Panel A: All Originations

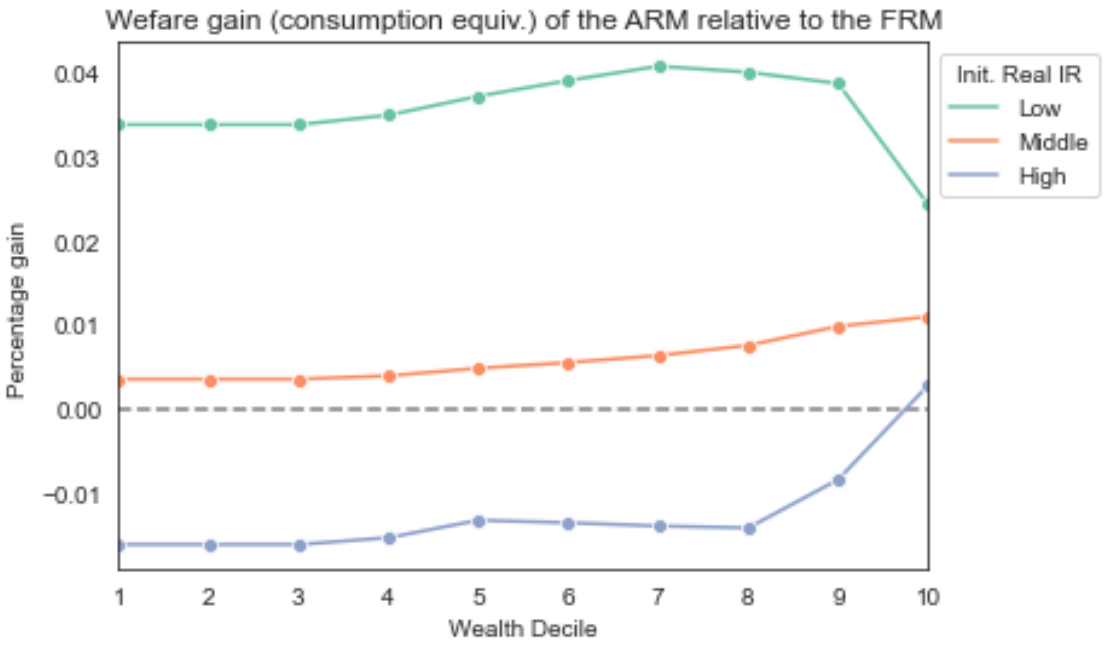


Panel B: New Purchase Subsample



Notes: Adjustable rate mortgage share by decile of observable net wealth (assets less debts). Panel A shows the full sample of new originations, which compares ARMs with any fixation period to all other mortgage types. Panel B shows the new purchase subsample which restricts to ARMs with very short fixation periods (1 year or less) and 30 year FRMs. Deciles are calculated relative to the sample in question. Error bars represent 95 percent confidence intervals.

Figure 9: Welfare Benefit of ARM Choice by Wealth and Initial Interest Rate



Notes: Consumption equivalent welfare gain of choosing an ARM versus an FRM by decile of initial wealth. The green line corresponds to an initial real interest rate of -2% and a FRM-ARM spread of 4%. The orange line corresponds to an initial real interest rate of 1.5% and a FRM-ARM spread of 1.5%. The blue line corresponds to an initial real interest rate of 5% and a negative FRM-ARM spread of -1%.

Table 1: Summary Statistics: Loan Data

	Panel A: All Originations				
	Mean	SD	P1	P50	P99
Mortgage Principal	1.29	0.94	0.12	1.10	4.32
Interest Rate	1.96	1.32	-0.22	2	5
Loan-to-Value Ratio	60.1	27.6	5.55	65.9	136.0
Interest Only	0.55	0.50	0	1	1
FRM	0.49	0.50	0	0	1
Capped ARM	0.036	0.19	0	0	1
ARM	0.45	0.50	0	0	1
Variable Rate	0.015	0.12	0	0	1
Observations	2036867				
	Panel B: New Purchase Subsample				
	Mean	SD	1st Pct.	Median	99th Pct.
Mortgage Principal	1.36	0.93	0.15	1.16	4.32
Interest Rate	2.31	1.22	-0.22	2	5
Loan-to-Value Ratio	64.8	21.8	8.31	75.6	91.7
Interest Only	0.49	0.50	0	0	1
FRM	0.78	0.41	0	1	1
ARM	0.22	0.41	0	0	1
Observations	297406				

Panel A displays summary statistics for all new mortgages originated between 2009-2018. Panel B shows summary statistics for a subsample of mortgages for new home purchases between 2010-2018. This subsample excludes refinances, non-concurrent additional liens, and mortgages for homeowners with multiple properties, and all mortgage types except standard 30 year FRMs and ARMs with short term (1 year or less) initial fixation periods. Mortgage principal is in millions of DKK.

Table 2: Summary Statistics: Household Data

	All Originations				
	Mean	SD	1st Pct.	Median	99th Pct.
Age of Oldest Member	47.5	13.5	23	46	80
Max Education Level	15.4	2.30	8	15	21
Economics Degree	0.099	0.30	0	0	1
Number of Children	0.84	1.03	0	0	3
Immigrant	0.084	0.28	0	0	1
Income	0.80	0.67	0.15	0.72	2.58
Housing Assets	2.28	3.22	0	1.76	10.3
Stocks	0.13	2.81	0	0	1.98
Bonds	0.027	0.55	0	0	0.43
Bank Deposits	0.27	0.62	0.00041	0.12	2.38
Mortgage Debt	1.93	2.75	0	1.50	8.53
Other Debt	0.41	1.65	0	0.20	3.55
Observations	2036867				
	New Purchase Subsample				
	Mean	SD	1st Pct.	Median	99th Pct.
Age of Oldest Member	40.3	13.7	21	37	79
Max Education Level	15.4	2.39	8	15.3	21
Economics Degree	0.091	0.29	0	0	1
Number of Children	0.60	0.89	0	0	3
Immigrant	0.12	0.33	0	0	1
Income	0.67	0.53	0.12	0.61	2.07
Housing Assets	1.81	2.95	0	1.36	8.79
Stocks	0.11	3.18	0	0	1.70
Bonds	0.023	0.53	0	0	0.32
Bank Deposits	0.23	0.63	0.00035	0.093	2.20
Mortgage Debt	1.57	2.35	0	1.23	6.28
Other Debt	0.41	1.29	0	0.24	3.11
Observations	297406				

Panel A displays summary statistics for households linked to all new mortgages originated between 2009-2018. Panel B shows summary statistics for households linked to a subsample of mortgages for new home purchases between 2010-2018. This subsample excludes refinances, non-concurrent additional liens, and mortgages for homeowners with multiple properties, and all mortgage types except standard 30 year FRMs and ARMs with short term (1 year or less) initial fixation periods. Max education level refers to the highest education level among members of the household. Income, housing assets, stocks, bonds, bank deposits, mortgage debt and other debt are all in millions of DKK.

Table 3: Parameter Summary

Description	**Parameter**	**Value**
Discount Rate	β	0.99
Risk Aversion	γ	2
Cobb-Douglas Housing	θ	0.2
Bequest Weight	b	25
Maximum Loan-to-Value	$\overline{LTV}$	0.8
Tax on Income/Capital Gains	τ	0.42
Initial Income Level (1000 DKK)	Y_0	663
Growth Rate of Income		0.011
SD of Permanent Income Shock	σ_η	0.11
SD of Temporary Income Shock	σ_ϵ	0.14
Initial Wealth (1000 DKK)	W_0	1,268
Equity Premium	μ_S	0.0224
SD of Stock Returns	σ_ζ	0.133
Mean Log Home Price Return	μ_H	0.0127
SD of Log Home Price Return	σ_ε	0.091
Mean of interest rate process	μ_r	0.026
Autoregression Parameter	ϕ	0.817
Std. Deviation of Interest Rate Shock	σ_ι	0.052
Interest rate premium for FRM	θ^{FRM}	0.0244
Interest rate premium for ARM	θ^{ARM}	0.01
Refinance Cost		$3000 + \max(0.002M_t, 4000) + 0.001M_t$
Corr. Perm. Income and Home Prices	$\rho_{\varepsilon\eta}$	0.016
Corr. Temp. Income and Interest Rates	$\rho_{\varepsilon\epsilon}$	0

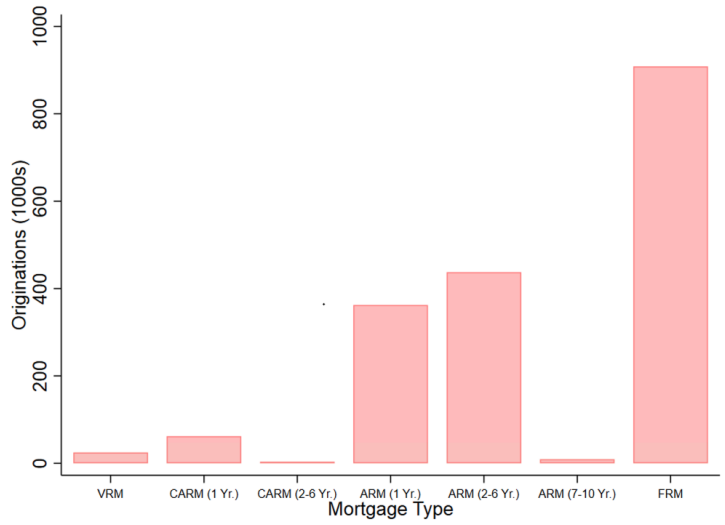
Table A.I: Deciles of Financial Wealth

Percentile	Net Wealth	Income	Assets	All Debt	Mortgage Debt	Bank Deposits	Bank Loans	Housing Assets	Stocks	Bonds	Private Loans	Fin. Assets	Net Fin.Wealth
10	-0.93	0.33	0.91	0.78	0.59	0.02	0.00	0.78	0.00	0.00	0.00	0.02	-0.66
20	-0.52	0.44	1.18	1.06	0.84	0.04	0.00	1.02	0.00	0.00	0.00	0.04	-0.39
30	-0.28	0.55	1.44	1.31	1.05	0.06	0.02	1.25	0.00	0.00	0.00	0.07	-0.23
40	-0.08	0.64	1.72	1.55	1.26	0.08	0.10	1.49	0.00	0.00	0.00	0.10	-0.11
50	0.12	0.72	2.02	1.81	1.49	0.12	0.19	1.76	0.00	0.00	0.00	0.15	0.00
60	0.35	0.80	2.36	2.12	1.77	0.17	0.29	2.04	0.00	0.00	0.00	0.22	0.07
70	0.64	0.90	2.81	2.50	2.11	0.24	0.41	2.40	0.01	0.00	0.00	0.32	0.16
80	1.07	1.03	3.47	3.04	2.58	0.36	0.56	2.95	0.04	0.00	0.00	0.49	0.32
90	1.89	1.26	4.83	4.08	3.47	0.61	0.88	4.01	0.19	0.00	0.00	0.89	0.66

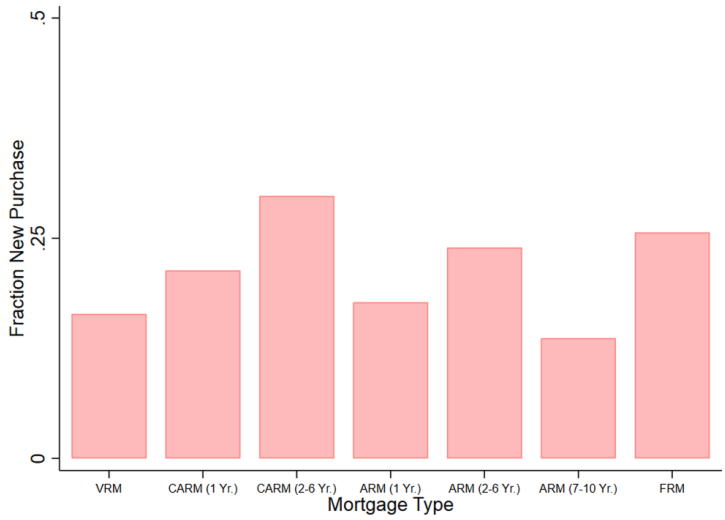
Deciles of financial variables in millions of DKK for households linked to the full sample of new originations. Net wealth refers to all observables assets less all observable debts. Fin. assets excludes housing assets and net fin wealth is measured as non-housing wealth less non mortgage debt. To avoid identifying individuals in the data, we do not report precise deciles, but rather the average of the 0.1 percent closest to the decile in question.

Figure A.I: Mortgage Originations Over Time

Panel A: Quantity of Mortgages by Type and Fixation Period



Panel B: Fraction of New Originations by Within Type and Fixation Period



Notes: Panel A shows the number of new mortgage originations in Denmark by mortgage type and fixation period in our matched household sample covering 2009-2018. Panel B shows the fraction in each that is classified as a new origination according to our definition.