Inattention and Inertia in Household Finance: Evidence from the Danish Mortgage Market

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Abstract

This paper studies the refinancing behavior of Danish households during a recent period of declining interest rates. Danish data are particularly suitable for this purpose because the Danish mortgage system imposes few barriers to refinancing, and demographic and economic characteristics of mortgage borrowers can be accurately measured. The paper finds that household characteristics affect both inattention (low responsiveness of mortgage refinancing to financial incentives) and inertia (low unconditional probability of refinancing). Many characteristics move inattention and inertia in the same direction, implying a high cross-sectional correlation of 0.82 between these two household attributes. Middle-aged and older households show greater inertia and inattention than young households do. Education and income reduce both inertia and inattention, but the effect of education is greater among more educated households while the effect of income is greater among poorer households. Wealth increases inertia and inattention among households in the upper half of the wealth distribution.

1 Introduction

Inertia, or sluggish adaptation to altered circumstances, is endemic in household financial decisionmaking. It has been documented for participation, saving, and asset allocation decisions in retirement savings plans (Agnew, Balduzzi, and Sunden 2003, Choi, Laibson, Madrian, and Metrick 2002, 2004, Madrian and Shea 2001) and for portfolio rebalancing in response to fluctuations in risky asset prices (Bilias, Georgarakos, and Haliassos 2010, Brunnermeier and Nagel 2008, Calvet, Campbell, and Sodini 2009).

Mortgage refinancing is one area where inertia appears to be particularly important. In the US fixed-rate mortgage (FRM) system, refinancing inertia is essential for understanding empirical prepayment behavior, the main preoccupation of a large literature on the pricing and hedging of mortgage-backed securities in the years before the global financial crisis of the late 2000s (Schwartz and Torous 1989, McConnell and Singh 1994, Stanton 1995, Bennett, Peach, and Peristiani 2001). Random time-variation in the degree of inertia accounts for prepayment risk, which in turn affects the pricing of mortgage-backed securities (Gabaix, Krishnamurthy, and Vigneron 2007). In the UK adjustable-rate mortgage (ARM) system, teaser rates also generate incentives to refinance, and here too many people fail to refinance when it would be optimal to do so (Miles 2004).

This evidence raises several interesting questions. First, are there measurable differences between people who refinance appropriately and those who fail to do so? Evidence from the US suggests that this is the case (LaCour-Little 1999, Campbell 2006, Schwartz 2006, Agarwal, Rosen, and Yao 2012). However, it is challenging to measure borrower characteristics in the US system since these are reported only at the time of a mortgage application through the form required by the Home Mortgage Disclosure Act (HMDA), and hence one cannot directly compare the characteristics of refinancers and non-refinancers at a point in time. An alternative is to use survey data, but these are extremely noisy (Schwartz 2006).

Second, how common are errors of commission, where households refinance their mortgages too soon, relative to errors of omission, where households refinance their mortgages too late or fail to refinance them at all? Agarwal, Driscoll, and Laibson (2013) point out that because interest rates are random and refinancing involves fixed monetary and time costs, the optimal refinancing decision is the solution to a real options problem. It is not optimal to refinance as soon as the interest savings cover the fixed costs of refinancing, because waiting may lead to a further interest saving if interest rates decline further. They present an approximate closed-form solution to the refinancing problem, which Agarwal, Rosen, and Yao (2012) use to measure omission and commission error rates. However Agarwal, Rosen, and Yao can only study delays in refinancing among refinancers, since they have no data on people who fail to refinance altogether.

Third, to what extent are failures to refinance driven by constraints such as poor credit ratings or negative home equity, versus failures to understand refinancing incentives? This

is a pervasive issue in empirical research using US data (Campbell 2006, Schwartz 2006). US government efforts to relax refinancing constraints have been an important theme of US housing policy in the aftermath of the global financial crisis.

In this paper we study refinancing decisions using data from Denmark. The Danish mortgage system is similar to the US system in that it is dominated by FRMs, but different in that households are free to refinance whenever they choose to do so, even if their home equity is negative or their credit standing has deteriorated, provided that they do not increase their principal balance. This allows us to study refinancing inertia without having to control for constraints. In addition, the Danish statistical system provides us with accurate administrative data on household demographic and financial characteristics, for all mortgage borrowers including both refinancers and non-refinancers.

We use the high-quality Danish data to measure how household characteristics affect the responsiveness of households to refinancing incentives, as well as the unconditional or baseline refinancing probability. In this way we relate refinancing inertia to inattention, the inability of households to accurately perceive and act upon incentives.

Our work fits into a broader literature on the difficulties households have in managing their mortgage borrowing. Campbell and Cocco (2003, 2014) specify models of optimal choice between FRMs and ARMs and optimal prepayment and default decisions, showing how challenging it is to make these decisions correctly. Chen, Michaux, and Roussanov (2011) similarly study decisions to extract home equity through cash-out refinancing, while Khandani, Lo, and Merton (2013) argue that households used cash-out refinancing to borrow too aggressively during the housing boom of the early 2000s. Bucks and Pence (2008) provide direct survey evidence that ARM borrowers are unaware of the exact terms of their mortgages, specifically the range of possible variation in their mortgage rates. Woodward and Hall (2010, 2012) study the fees that borrowers pay at mortgage origination, arguing that insufficient shopping effort leads to excessive fees, particularly for less sophisticated borrowers.

The organization of the paper is as follows. Section 2 explains the Danish mortgage system and household data. Section 3 presents a model of inattention and inertia. Section 4 estimates the model empirically, and section 5 concludes.

2 The Danish Mortgage System and Household Data

2.1 The Danish mortgage system

The Danish mortgage system has attracted considerable attention internationally because, while similar to the US system in offering long-term fixed-rate mortgages without prepayment penalties, it has numerous design features that differ from the US model and have performed well in recent years (Campbell 2013, Gyntelberg et al. 2012, Lea 2011). In this section we briefly review the funding of Danish mortgages and the rules governing refinancing.

A. Mortgage funding

Danish mortgages, like those in some other continental European countries, are funded using covered bonds: obligations of mortgage lenders that are collateralized by pools of mortgages. The Danish mortgage bond market is one of the largest in the world, both in absolute terms and relative to the size of the economy. The market value of all Danish outstanding mortgage bonds in 2012 was DKK 2,456bn (EUR 330bn), exceeding the Danish GDP of DKK 1,826bn (EUR 245bn). In Europe, only Germany has a bigger market than Denmark in absolute terms.

Mortgages in Denmark are issued by mortgage banks that act as intermediaries between investors and borrowers. Investors buy mortgage bonds issued by the mortgage bank, and borrowers take out mortgages from the bank. All lending is secured and mortgage banks have no influence on the yield on the loans granted, which is entirely determined by the market. There is no direct link between the borrower and the investor. Instead investors buy bonds that are backed by a pool of borrowers. If a borrower defaults, the mortgage bank must replace the defaulted mortgage in the pool that backs the mortgage bond. This ensures that investors are unaffected by defaults in their borrower pool so long as the mortgage bank remains solvent.

In the event of a borrower default, the mortgage bank can enforce its contractual right by triggering a forced sale (foreclosure) which is carried through by the enforcement court, part of the court system in Denmark. To the extent that the proceeds of a forced sale are insufficient to pay off mortgages, uncovered claims are converted to personal claims held by the mortgage bank against the borrower. In other words Danish mortgages (like those elsewhere in Europe) have personal recourse against borrowers.

The Danish mortgage system originated in 1795 when a huge fire burned one in four houses in Copenhagen to the ground. To finance the reconstruction, lenders formed a mortgage association in 1797 and the first Danish mortgages were issued on real property on the basis of joint and several liability to enhance credit quality. Over the past 200-plus years the market has experienced no mortgage bond defaults, and only in a very few cases have

payments to investors been delayed. The last example of delayed payments to mortgage bond investors occurred in the 1930s.

This track record is partly attributable to a strong legal framework. The first legal framework was introduced in 1850, and the current framework is from 2007. The legal framework is designed to protect mortgage bond investors and confines the activities of mortgage banks to mortgage lending funded only through the issuance of mortgage bonds. Mortgage loans serving as collateral must meet restrictive eligibility criteria including LTV limits and valuation of property requirements laid down in the legislation. For instance, for private residential properties the LTV limit is 80% and mortgage banks are obliged to assess the market value of pledged properties at the time of granting the loans. The maximum loan maturity is 30 years, with an option for interest-only periods of a maximum of 10 years for private residential properties. Mortgage banks may not grant loans exceeding these limits, even to borrowers who are extremely creditworthy.

Today, Danish mortgage bonds are issued by seven mortgage banks. Mortgages on various types of real properties are eligible as collateral for mortgage bonds. However, mortgages on residential properties dominate most collateral pools. Owner-occupied housing makes up around 60% of mortgage pools, followed by around 20% for rental and subsidised housing. Agriculture and commercial properties make up the remaining 20% of the market.

B. Refinancing

Mortgage borrowers in Denmark have the right to prepay their mortgages without penalty. This is similar to the US system but differs from the German system, where a fixed-rate mortgage can only be prepaid at a penalty that compensates the mortgage lender for any decline in interest rates since the mortgage was originated. However the prepayment system in Denmark also differs from the US system in several important respects.

The Danish mortgage system imposes minimal barriers to any refinancing that does not increase the principal balance of a mortgage. Danish borrowers can refinance their mortgages to reduce their interest rate and/or extend their loan maturity, without increasing their principal balance, even if their homes have declined in value so they have negative home equity. Related to this, fixed-principal refinancing does not require a review of the borrower's credit quality. Denmark does not have a system of continuous credit scores like the widely used FICO scores in the US. Instead, there is what amounts to a zero/one scoring system that can be used to label an individual as a delinquent borrower (dårlig betaler) who has unpaid debt outstanding. A delinquent borrower would be unlikely to obtain a mortgage, but a borrower with an existing mortgage can refinance (without increasing the principal balance) even if he or she has been labeled as delinquent since the mortgage was taken out. These features of the system imply that all mortgage borrowers can benefit from a decline in interest rates, even in a weak economy with declining house prices and consumer deleveraging.

Cash-out refinancing that increases mortgage principal does require sufficiently positive home equity and good credit status. For this reason, cash-out refinancing has been uncommon in Denmark since the onset of the housing downturn in the late 2000s.

The mechanics of refinancing in Denmark are as follows. The mortgage borrower must repurchase mortgage bonds corresponding to the mortgage debt, and deliver them to the mortgage lender. This repurchase can be done either at market value or at face value. The option to refinance at market value becomes relevant if interest rates rise; it prevents "lock-in" by allowing homeowners who move to buy out their old mortgages at a discounted market value rather than prepaying at face value as would be required in the US system. It also allows homeowners to take advantage of disruptions in the mortgage bond market by effectively buying back their own debt if a mortgage-bond fire sale occurs. In an environment of declining interest rates, the option to refinance at face value is relevant.

An important point is that mortgage bonds in Denmark are issued with discrete coupon rates, historically at integer levels such as 4% or 5%.[2] Market yields, of course, fluctuate continuously. Thus in order to raise, say, DKK 1 million (about $190,000 or EUR 130,000) for a mortgage, bonds must be issued with a face value that differs from DKK 1 million whenever the market yield differs from the coupon rate. Refinancing a mortgage requires buying the full face value of the bonds that were issued to finance the mortgage. This means that the incentive to refinance in the Danish system is given by the spread between the coupon rate on the old mortgage bond (not the yield on the mortgage when it was issued) and the yield on a new mortgage.

2.2 Danish household data

A. Data sources

We assemble a unique dataset from Denmark. Our dataset covers the universe of adult Danes in the period between 2008 and 2012 and contains demographic, and economic information. We derive data from five different administrative registers made available through Statistics Denmark.

We obtain mortgage data from the Association of Danish Mortgage Banks (Realkreditrådet) and the Danish Mortgage Banks' Federation (Realkreditforeningen). The data cover the 5 largest mortgage banks with an aggregated market share of 94.2% of the market value of all mortgages in Denmark. The residual mortgages are issued by two smaller mortgage banks. The data contain the personal identification number of borrowers, as well as a mortgage id, and information on the terms of the mortgage (principal, outstanding principal,

[2]More recently, bonds have been issued with non-integer coupons in response to the current low-interest-rate environment.

coupon, annual fees, maturity, loan-to-value, etc.) The mortgage data are available from 2009 to 2011.

We obtain demographic information from the official Danish Civil Registration System (CPR Registeret). These records include the individual's personal identification number (CPR), as well as their name; gender; date of birth; and the individual's marital history (number of marriages, divorces, and widowhoods). The administrative record also contains a unique household identification number, as well as CPR numbers of each individual's spouse and any children in the household. We use these data to obtain demographic information about the borrower. The sample contains the entire Danish population and provides a unique identifying number across individuals, households, and time.

We obtain income and wealth information from the official records at the Danish Tax Authority (SKAT). This dataset contains total and disaggregated income and wealth information by CPR numbers for the entire Danish population. SKAT receives this information directly from the relevant third-party sources, because 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, the income and wealth information are highly reliable.

Some components of wealth are not recorded by SKAT. The Danish Tax Authority does not have information about individuals' holdings of cash (outside bank accounts), the value of their cars, their private debt (i.e., debt to private individuals), pension savings, private businesses, or other informal wealth holdings. This leads some individuals to be recorded as having negative net financial wealth because we observe debts but not corresponding assets, for example in the case where a person has borrowed to finance a new car.

We obtain the level of education from the Danish Ministry of Education (Undervisningsministeriet). This register identifies the highest level of education and the resulting professional qualifications. On this basis we calculate the number of years of schooling.

Finally, we use data on medical treatments and hospitalizations from the Danish National Board of Health (Sundhedsstyelsen) to calculate the total number of days in hospital during the year. This dataset records medical treatments and discharges from hospitals. Diagnosis and treatments are classified according to the WHO's ICD-10 system.[3]

[3]WHO's International Classification of Diseases, ICD-10, is the latest in a series that has its origin in the 1850s. WHO took over the responsibility for ICD at its creation in 1948. The system is currently used for mortality and morbidity statistics by all member states.

B. Sample selection

Our sample selection entails linking individual mortgages to the household characteristics of borrowers. We define a household as one or two adults living at the same postal address. According to this definition we identify 2,727,791 households in 2011 (2,709,304 in 2010 and 2,691,078 in 2009). Out of these 2,727,791 households we are able to match 2,459,496 households to a complete set of information on income and education. For the remaining households we have incomplete information, primarily because the individual lives abroad and, therefore, does not pay income tax.[4] To be able to credibly track the ownership of each mortgage we additionally require that each household is stable and present in the data over the sample period from 2009 to 2011. Thus, we require that the number of adults in the households is constant, and that the household does not move. As a result the sample is reduced to 2,037,122 households in each year.

To operationalize our analysis of refinancing within fixed-rate mortgages we start by identifying households with a single fixed-rate mortgage. This is done in three steps. First we identify 823,891 households with a mortgage. Second, we focus on households with a single mortgage. Out of 823,891 households with mortgages, 592,221 households have a single mortgage. Third, we focus on households that have fixed-rate mortgages. We include households in the sample if they have i) a fixed-rate mortgage both in 2009 and 2010, or ii) a fixed-rate mortgage both in 2010 and 2011. This leaves us with 254,292 households for the 2009 to 2010 refinancing decision, and 248,027 households for the 2010 to 2011 refinancing decision. Thus, in total we have 502,319 observations in the analysis.

Collectively, our selection criteria ensure that refinancing occurs for economic reasons rather than a household-specific event, such as a move, which causes the mortgage to mature by default. Refinancing in our sample occurs when a household changes from one fixed-rate mortgage to another fixed-rate mortgage on the same property.

C. Descriptive statistics

Table 1 summarizes the characteristics of fixed-rate mortgages and households' propensity to refinance them. These characteristics are broken out by the annual coupon rate on the underlying mortgage bonds. In addition to the annual coupon, borrowers pay an administration fee to the mortgage bank, which is roughly 70 basis points on average, and depends on the loan-to-value (LTV) ratio on the mortgage, but is independent of household characteristics

The average fixed-rate mortgage has an outstanding principal of DKK 867,000 (about $165,000 or EUR 113,000) and 22.4 years to maturity by the end of 2009. The outstanding

[4]We also drop households whose educational records are missing—which typically occurs because they obtained their education abroad.

principal corresponds to a loan-to-value ratio of 51.6%. From 2009 to 2010 10.6% of all fixed-rate mortgages in our sample were refinanced. As expected, the refinancing probability depends on the coupon rate of the mortgage bond underlying the old mortgage. For mortgages with a coupon of 3% and 4% the propensities to refinance are 2.3% and 2.2%, respectively.[5] For mortgages with a 5% coupon, which in 2009 accounted for roughly half of all fixed-rate mortgages, the propensity to refinance is 8.1%. The propensities to refinance are 38.9% and 32.3% for mortgages with coupon rates of 6% and 7% or more, respectively.

In 2011 the propensity to refinance was lower than in 2010. In total only 2.8% of all fixed-rate mortgages were refinanced. Still, we again see an increasing propensity to refinance as the coupon rate increases. For 3% coupon mortgages the propensity to refinance was a modest 1.7%, while the propensity for mortgages with a 6% coupon or more was 7.8%.

In our empirical analysis we use ranks of income, financial wealth, education, and age rather than the actual values of these variables. Table 2 reports descriptive statistics on income, financial wealth, education and age for households with a fixed-rate mortgage. We report the underlying distribution for all households, and for refinancing and non-refinancing households, respectively. Across the distribution we find very few differences between refinancing and non-refinancing households. Income seems to be slightly higher across the distribution for refinancing households, while there are no systematic patterns for financial wealth and education. We do see that refinancing households tend to be younger across the entire cross-sectional age distribution.

Table 3 provides descriptive statistics for all households with a fixed-rate mortgage and a comparison of household characteristics between refinancing and non-refinancing households. Around 25% of all households consist of a single member, and 64% are married couples. The residual 11% are cohabiting couples. Around 40% of the households have children living in the household, and 12.3% live in a metropolitan area (greater Copenhagen). Table 3 also reports that 1.2% of the households got married within the year, and that 3.4% of all households have their first child within the year. Around 10% of all households experience a negative health shock during the sample period. We define a negative health shock as occurring whenever a member of a household receives medical treatment at a hospital (on an inpatient or outpatient basis) on 5 days or more during the year, and received such treatment on fewer than 5 days in the year before.

Columns 2 to 7 of Table 3 report differences in household characteristics between refinancing and non-refinancing households. A positive number means that the average characteristic is larger for refinancing households than for non-refinancing households. Column 2 shows that refinancing households are more likely to be married rather than single, are more likely to get married and have their first child, and less likely to have a negative health shock.

[5] Mortgage bonds with a 3% coupon were issued in 2005 during a previous period of relatively low mortgage rates. Most of the underlying mortgages for these bonds have a relatively low maturity of 10 years, or in some cases 20 years. These mortgages account for only a very small fraction of our dataset.

3 A Model of Inattention and Inertia

We specify a model of mortgage choice in which the probability that a household refinances its fixed-rate mortgage is determined by the financial incentive to refinance, as well as the level of attention that the household devotes to this incentive. The form of the model is

$$\Pr(\text{Refinancing}) = \Pr(\gamma' b_{it} + A(\delta' s_{it}) I(z_{it}) + \epsilon_{it}) > 0,\ \epsilon_{it} \ \sim \ N(0, \Sigma). \tag{1}$$

Here the vectors b_{it} and s_{it} contain characteristics of household i at time t. The characteristics in the vector b_{it} determine the baseline probability of refinancing, while those in the vector s_{it} shift attention—that is, they determine the responsiveness of the household to refinancing incentives. The vector $z_{i,t}$ contains characteristics of the household's mortgage at time t.

$A(.)$ is the index of attention for household i at time t, and $I(.)$ is the function determining the household's incentive to refinance. We use an exponential form for the attention function:

$$A(\delta' s_{it}) = \exp(\delta' s_{it}). \tag{2}$$

This is defined for all values of s_{it} and is always non-negative to avoid perverse reactions to incentives. As $A(s_{it}) \to 0$ the household ignores the incentive to refinance and its refinancing probability is determined by the baseline refinancing probability. As $A(s_{it}) \to \infty$ the household reacts sharply to any incentive; if the incentive is positive (negative), the household always (never) refinances.

We define the incentive to refinance as the interest rate on a new mortgage relative to the coupon rate on the mortgage bond corresponding to the current mortgage, less a threshold level $O(z_{it})$:

$$I(z_{it}) = C_{it}^{old} - Y_{it}^{new} - O(z_{it}). \tag{3}$$

The function $O(z_{it})$ captures a variety of costs associated with refinancing. These costs include fixed monetary costs, for example legal fees; non-monetary costs of refinancing such as search and information processing costs; and the option value of waiting for further interest-rate declines.

In our empirical analysis we define the threshold function to be the second order approximation of the option value in Agarwal, Driscoll, and Laibson (ADL 2013), i.e.,

$$O(z_{it}) \approx \sqrt{\frac{\sigma \kappa_{it}}{m_{it}(1-\tau)} \sqrt{2(\rho + \lambda_{it})}}, \tag{4}$$

where $m_{i,t}$ is the size of the mortgage for household i at time t, λ_{it} is the probability of forced refinancing, and κ_{it} is the fixed cost of refinancing. All of these parameters can in principle vary across households. Marketwide parameters include σ, the volatility of the interest rate; τ, the marginal tax rate that determines the tax benefit of mortgage interest deductions; and ρ, the discount rate.

Following ADL we define λ_{it} and κ_{it} as

$$\lambda_{it} = \mu_{_{it}} + \frac{Y_{_{it}}^{old}}{\exp(Y_{it}^{old} T_{_{it}}) - 1} + \pi_t, \tag{5}$$

$$\kappa_{it} = f + \theta m_{it}. \tag{6}$$

Here $\mu_{_{it}}$ is the household's moving probability, T_{it} is the number of years remaining on the mortgage, π_t is the inflation rate, f is the fixed cost of refinancing, and θ is the capital loss in basis points on the mortgage if it is refinanced.

Our initial model is calibrated to Danish data as follows: $\sigma = 0.0109, \tau = 0.33, \rho = 0.06, \mu = 0.1$, $\theta = 0.01$, and $f =$ DKK 10,000 (about \$1,900 or EUR 1,300). π_t is calculated from the Danish consumer price index. In further analysis we will estimate $\mu_{i,t}$ at the household level and use this to generate variation between households in $\lambda_{i,t}$.

A hypothesis we explore in this paper is that household characteristics affect the baseline refinancing probability and the attention function in the same proportion. To test this hypothesis we set $b_{it} = s_{it}$ and estimate

$$\Pr(\text{Refinancing}) = \Pr(\gamma' b_{it} + A(k\delta' s_{it}) I(z_{it}) + \epsilon_{it}) > 0, \ \epsilon_{it} \ \sim \ N(0, \Sigma). \tag{7}$$

We calculate a likelihood ratio test from estimates of an unconstrained model setting $k = 1$, and a constrained model with a free k and $\gamma = \delta$ for all elements except the constants.

4 Empirical Results

4.1 Refinancing incentives and mistakes

During our sample period Danish mortgage rates declined from the levels that had prevailed in the late 2000s, back to levels last seen in 2005. This pattern is illustrated by Figure 1, which plots the history of 30-year Danish mortgage rates from 2003. In the middle of 2010 the mortgage rate bottomed out just above 4%, before rising back above 5% in early 2011, and then declining again to 4% later in the year. In our data analysis we treat each year as a single observation, and use the lowest mortgage rate during the year to calculate refinancing incentives.

Table 4 summarizes the cross-sectional distribution of refinancing incentives. The top panel of the table shows the interest rate spread between the coupon rate on the mortgage bond corresponding to the old mortgage, less the currently available mortgage rate (calculated as the minimum observed 30-year mortgage rate in 2010 and 2011 respectively.) The median interest spread was 80 basis points in 2010 and 110 basis points in 2011, with wide cross-sectional variation. In 2010, for example, the 5th percentile of the interest rate spread was –20 basis points, while the 95th percentile was 180 basis points.

The second panel of the table reports the Agarwal, Driscoll, and Laibson (ADL 2013) threshold that justifies refinancing. The median threshold is about 155 basis points in both years, with again a wide cross-sectional variation from 123 basis points at the 5th percentile to 248 basis points at the 95th percentile. The cross-sectional distribution of thresholds is right-skewed because, in the presence of fixed refinancing costs, a very high interest saving is needed to justify refinancing a small mortgage or a mortgage with only a few years left to maturity.

The third panel subtracts the ADL threshold from the interest rate spread for each mortgage to calculate the overall refinancing incentive. The median incentive was negative at –90 basis points in 2010 and –112 basis points in 2011, indicating that most mortgage borrowers should not have refinanced in these years. However, there is an important right tail of mortgages with positive refinancing incentives. The 95th percentile incentive was 43 basis points in 2010 and 16 basis points in 2011.

A simple way to use these estimates is to calculate the incidence of refinancing mistakes. These fall into two main categories. Borrowing the terminology of Agarwal, Rosen, and Yao (2012), "errors of commission" are refinancings that occur an interest-rate saving below the ADL threshold, while "errors of omission" are failures to refinance that occur above the ADL threshold. To take account of uncertainty in the ADL threshold, we can impose an additional error threshold of k percentage points. Table 5 reports the frequency of these two types of error, conditional on the mortgage having an interest rate below the ADL threshold less k% (for errors of commission) or above the ADL threshold plus k% (for errors of omission). The table shows that in our sample period, far more mortgages have negative refinancing incentives (460,831 in the case of $k = 0$) than have positive refinancing incentives (41,473 in the case of $k = 0$). However, within the large first group errors of commission are relatively rare, occurring about 4% of the time for error thresholds $k = 0$ or $k = 0.25$. Within the small second group errors of omission are quite common, occurring almost 64% of the time for $k = 0$ and 58% of the time for $k = 0.25$. These facts are not surprising, since errors of omission before the start of our sample period are necessary for large positive refinancing incentives to be observed in our dataset. They do provide some support for the focus of the literature (e.g. Campbell 2006 and Miles 2004) on errors of omission.

In Table 6 we relate errors of commission and errors of omission to demographic characteristics of households. The left hand panel of the table has an error threshold $k = 0$, while the right hand panel sets $k = 0.25$. For households with incentives below or above the threshold, we report the mean characteristics for households that do or do not refinance. Errors of commission are in the first column, while errors of omission are in the fourth column.

A number of household characteristics appear to be associated with both types of mistakes, in a manner that is robust to the choice of error threshold. For example, single-person households are more likely to refinance when their mortgage rate is below the threshold (an error of commission), but less likely to refinance when their mortgage rate is above the thresh-

old (an error of omission). The opposite is the case for married households and households with children. Among the ranked characteristics, we see that older households, less educated households, and lower-income households are all more likely to make both types of refinancing mistake.

These results motivate a more careful econometric analysis of the determinants of refinancing, distinguishing inertia and inattention using the model of the previous section.

4.2 Estimating inattention and inertia

A. Simple probit analysis of refinancing

We begin by estimating a version of equation (1) that omits any information on the magnitude of the refinancing incentive, and simply uses household economic and demographic refinancing to predict refinancing. These results are reported in Table 7.

We estimate three models that include the same dummy variables, but differ in their treatment of ranked variables (age, years of education, income, and financial wealth). Agarwal, Driscoll, Gabaix, and Laibson (2009) report that age has a nonlinear effect on many financial decisions, with financial sophistication increasing among younger people as they gain experience, and decreasing among older people perhaps because of cognitive decline. Education, income, and wealth may also have different effects among less educated and poorer people than among better educated and richer people. We therefore want to allow for nonlinear effects of the ranked variables on refinancing probabilities.

Model 1 enters our ranked variables linearly. Model 2 adds the absolute value of the demeaned rank, a V-shaped function with the bottom of the V at the median household. In effect this allows a different slope on the ranked variables for households above and below the median. Model 3 replaces the absolute value of the demeaned rank with twice the squared demeaned rank. This is a U-shaped function with the bottom of the U at the median household, normalized in such a way that the average slope above the median and the average slope below the median are the same as in model 2 if the coefficients are equal. By comparing the coefficients estimated in model 2 and model 3, we can make sure that any nonlinear effects are robust to the exact manner in which nonlinearity is modeled.

The main results in Table 7 are as follows. First, relative to baseline households (unmarried cohabiting couples), single male and female households are somewhat less likely to refinance, but married couples behave very similarly to cohabiting couples. Second, discretionary life events (getting married or having children) increase the probability of refinancing but health problems reduce it. Third, older heads of household are less likely to refinance. The nonlinear models show that the negative effect of age is much stronger among younger-than-average people than among older-than-average people. Fourth, education increases

the probability of refinancing and the effect appears to be almost linear. Fifth, income and wealth have hump-shaped effects on refinancing probability. This probability increases strongly with income and wealth among below-median households, but decreases (weakly for income and strongly for wealth) among above-median households. Finally, the coefficients are quite similar across model 2 and model 3 so the exact specification of nonlinear rank effects is immaterial for the results.

B. Models with incentives

The results in Table 7 are misleading if households respond to financial incentives to refinance, and demographic characteristics are correlated with those incentives (perhaps through the date at which preexisting mortgages were taken out). In Table 8 we estimate some models that include simple incentive effects.

The columns headed "Baseline Probability" allow incentives to matter but they are constrained to do so equally across households. In other words the incentive effect is $\exp(\delta)$ for all households. We estimate δ to be about -0.43 in each of models 1, 2, and 3, implying that a 1% increase in the refinancing incentive increases the incentive-related term in equation (1) by $\exp(-0.43) = 0.65$. The coefficients on demographic variables are generally similar to the values reported in Table 4, implying that demographic effects are largely robust to consideration of incentives. Specifically, it remains true that singles are somewhat less likely to refinance than couples, and people getting married or having their first child are more likely to refinance while people with health difficulties are less likely to do so. Age continues to have a negative effect on refinancing probability (although this effect no longer flattens out at older ages). Education, income, and wealth now look very similar to one another in that all have hump-shaped effects on refinancing probability. In the lower half of the distribution, all these variables have strong positive effects on refinancing, but these effects reverse in the upper half of the distribution. Once again, these results are consistent across models 2 and 3, indicating robustness to the exact specification of nonlinearity.

The columns in Table 8 headed "Attention" allow household characteristics to affect the sensitivity of households to refinancing incentives. However characteristics are not allowed to affect the baseline refinancing probability, so all factors that diminish attention shrink the refinancing probability to a common value determined by the negative constant term in the regression. We find a mixture of results, some more intuitive than others. Education, for example, has a positive effect on attention in the upper half of the education distribution, and income has a positive and almost linear effect on attention. Wealth has a negative effect on attention in the upper half of the wealth distribution. This may capture an effect discussed by Agarwal, Rosen, and Yao (2012), that borrowers pay more attention when their mortgages are relatively more important to them.

Table 9 reports estimates of our full model that allows household characteristics to affect both the baseline probability of refinancing, and the response to incentives. Focusing on

the results for model 3, we see that single males have a lower refinancing probability and pay little attention to incentives; single females have higher attention to incentives; families with children have both a higher baseline refinancing probability and greater sensitivity to incentives; and negative health shocks reduce both baseline refinancing and attention to incentives, while deliberate changes in status (getting married or having a first child) have the opposite effect.

Turning to the ranked variables, many patterns are consistent across baseline refinancing probability and the response to incentives. Age reduces both of these among younger people, education increases both of them particularly (in the case of attention) among more educated people, income increases both of them particularly among poorer people, and wealth reduces both of them among wealthier people. These patterns are summarized visually in Figure 2, which plots the refinancing probability against the incentive to refinance. Each panel of Figure 2 shows the curve for a typical household, and the curves for a household with average characteristics except for one (the rank of age, education, income, or wealth) which is varied between the 10th and the 90th percentile. Of course, these characteristics typically covary but this is not taken into account in these figures, which vary the characteristics one at a time.

Because Table 9 shows that many characteristics move the baseline refinancing probability and the response to incentives in the same direction, in Table 10 we estimate and test a specification in which the two sets of coefficients are proportional except for the constant terms. We do this for our linear model 1 and one of our two nonlinear models, model 3. We estimate the coefficient of proportionality to be about 2, since the coefficients on attention are often about twice as large as the baseline coefficients. However the proportionality restriction is strongly rejected.

A visual impression of the fit of a proportional model is provided in Figure 3. This figure shows a scatterplot of the estimated baseline function $\gamma' b_{it}$ against the estimated sensitivity to incentives $\delta' s_{it}$ (the argument of the attention function), estimated using model 3 in Table 9. There is a strong positive correlation of 0.82 between these two quantities, but the figure illustrates considerable variation away from a proportional model which would place all the points on a straight line.

5 Conclusion

In this paper we have presented a preliminary analysis of sluggish mortgage refinancing behavior among Danish households. The Danish context is particularly advantageous for studying this type of household behavior because the Danish mortgage system places almost no restrictions on refinancing that does not involve cash-out (an increase in mortgage principal), so households that pass up opportunities to substantially reduce their mortgage costs are not constrained but are making mistakes in managing their finances. In addition, the Danish statistical system allows us to measure demographic and economic characteristics of households, and to use them to predict refinancing probabilities.

We distinguish between inertia (an unconditionally lower refinancing probability) and inattention (a reduced sensitivity to refinancing incentives). We find that many household characteristics move inertia and inattention in the same direction. Middle-aged and older households show greater inertia and inattention than young households do. Education and income reduce both inertia and inattention, but the effect of education is greater among more educated households while the effect of income is greater among poorer households. Wealth increases inertia and inattention, but the effect is important only among households in the upper half of the wealth distribution. In our whole sample, the unconditional cross-sectional correlation between inertia and inattention is 0.82.

This first version of our paper has several limitations. Three of these are particularly important and we plan to address them in the next draft of the paper. First, we have not taken any account of heterogeneity in moving probabilities across households, which may affect optimal refinancing decisions. Second, we have focused on interest-rate reduction as the motive for refinancing, and have not considered maturity extension. Third, we have not used information on the exact timing of refinancing within the year, instead treating each of the two years in our sample, 2010 and 2011, as single periods with a single prevailing interest rate.

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Table 1: Characteristics of Danish Fixed Rate Mortgages

The average characteristics in Panel A (B) are calculated using mortgages taken by all stable households in Denmark with a single fixed rate mortgage in 2009 and 2010 (2010 and 2011). The first five columns show the statistics broken out by the annual coupon rate on these mortgages, and the final column in each panel shows the statistics across all mortgages in each of the periods. The rows show, in order, the fraction refinancing, which is the fraction of households who did not move house, and refinanced their mortgage; the principal remaining in Danish Kroner, i.e., the outstanding principal on the mortgage; the years remaining before the mortgage matures; the Loan-to-value (LTV) ratio calculated by the mortgage bank; and the number of observations in each coupon group and in the overall dataset.

Panel A: 2009- 2010

	3% Coupon	4% Coupon	5% Coupon	6% Coupon	>6% Coupon	Total
Fraction refinancing	0.023	0.022	0.081	0.389	0.323	0.106
Principal remaining (Millions DKK)	0.377	0.869	0.906	0.873	0.572	0.867
Years remaining on mortgage	7.528	20.648	23.797	24.288	21.777	22.343
Loan-to-value (LTV) on mortgage	0.221	0.479	0.548	0.562	0.445	0.516
# of observations	7,701	79,254	129,230	32,738	5,368	254,292

Panel B: 2010- 2011

	3% Coupon	4% Coupon	5% Coupon	6% Coupon	>6% Coupon	Total
Fraction refinancing	0.017	0.014	0.034	0.078	0.078	0.028
Principal remaining (Millions DKK)	0.550	1.011	0.855	0.565	0.345	0.889
Years remaining on mortgage	9.526	22.665	22.820	20.960	18.165	22.081
Loan-to-value (LTV) on mortgage	0.345	0.608	0.589	0.491	0.357	0.579
# of observations	9,054	112,640	106,522	16,738	3,059	248,013

Table 2: Underlying Distribution of Ranked Variables

The percentiles of the distribution reported in the column headings are calculated across our sample of all stable households in Denmark with a fixed rate mortgage, pooling data over 2010 and 2011. The blocks of statistics refer to Income (defined as total taxable income for each household in million DKK), Financial wealth (defined as the value of cash, bonds, stocks and mutual funds less non-mortgage debt, in million DKK), Education (defined as the number of years it takes to reach the highest level of education of any individual in the household), and Age (measured in years). Within each block of statistics, percentiles are calculated for all households, and separately for the sub-populations of refinancing and non-refinancing households.

	Min	*1%*	*5%*	*10%*	*25%*	*Median*	*75%*	*90%*	*95%*	*99%*	*Max*
						Income					
All	-7.943	0.082	0.142	0.184	0.264	0.412	0.540	0.680	0.800	1.163	28.864
Refinancing	-1.303	0.113	0.174	0.215	0.312	0.447	0.565	0.701	0.826	1.195	6.767
Non-refinancing	-7.943	0.078	0.140	0.182	0.261	0.409	0.538	0.678	0.798	1.160	28.864
						Financial Wealth					
All	-112.205	-1.024	-0.487	-0.340	-0.139	0.028	0.194	0.474	0.750	1.762	174.833
Refinancing	-23.962	-1.075	-0.511	-0.361	-0.156	0.022	0.161	0.382	0.595	1.366	28.280
Non-refinancing	-112.205	-1.017	-0.485	-0.338	-0.138	0.028	0.196	0.481	0.760	1.789	174.833
						Education					
All	7	7	7	10	12	12	16	18	18	18	20
Refinancing	7	7	9	10	12	12	16	18	18	18	20
Non-refinancing	7	7	7	10	12	12	16	18	18	18	20
						Age					
All	21	26	31	35	42	53	63	70	75	83	96
Refinancing	21	26	30	33	39	49	60	67	71	79	91
Non-refinancing	21	27	31	35	43	53	63	71	76	84	96

Table 3: Differences in Household Characteristics: Refinancing and Non-Refinancing Households

The first column shows the average of each of the characteristics reported in the rows, computed using the entire sample of stable household in Denmark with a fixed rate mortgage, pooling data over 2010 and 2011. Columns 2 to 7 report the difference of means between refinancing and non-refinancing households, either unconditionally across the entire sample period (Column 2) or conditional on sub-periods (Columns 3 and 4), or conditional on other household characteristics (Columns 5 through 7). A negative value indicates that refinancing households have a lower mean value. Columns 3 and 4 report these differences in 2010 and 2011, respectively. Column 5 reports differences in means only for the well-educated households, defined as the upper 25% of the sample population. Column 6 reports the differences in means for married households. Column 7 reports differences in means for the wealthy households (those in the upper quartile of net financial wealth in the sample). The rows describe the characteristics; single households (male or female) are defined as households with only one adult living at the address, and represent 13% of the entire sample. "Married" households are defined as households with two legally bound adults (which includes registered partnership of same-sex couples). "Children in family" is an indicator for households with resident children. Metropolitan is an indicator for households living in greater Copenhagen. "Getting married" is an indicator which indicates a change in marital status over the sample period. "Having Children" is an indicator for households having their first child. "Rank of Age" is the rank of the age of the oldest person living in the household. "Rank of Education" is the rank of the best educated individual in the household. "Rank of Income (financial wealth)" is the rank of the total income (financial wealth) of the household. All rank variables are normalized such that they take values between -0.5 and 0.5.

		Difference of Refinancing and Non-Refinancing Households					
	Average	All	2010	2011	Educated	Married	Wealthy
Single male household	0.130	-0.041***	-0.045***	-0.029***	-0.018***		-0.027***
Single female household	0.126	-0.033***	-0.036***	-0.025***	-0.027***		-0.021***
Married household	0.642	0.042***	0.050***	0.001***	0.010***		0.041***
Children in family	0.396	0.104***	0.110***	0.044***	0.078***	0.079***	0.079***
Metropolitan property	0.127	0.000	0.000	-0.010**	0.000	0.006***	0.015***
Getting married	0.012	0.010***	0.009***	0.001	0.010***	0.011***	0.004***
Change to health	0.108	-0.015***	0.005***	0.004	-0.007***	-0.011***	-0.017***
Having children	0.034	0.022***	0.022***	0.007***	0.021***	0.017***	0.011***
Rank of age in years	0.000	-0.076***	-0.081***	-0.020***	-0.063***	-0.063***	-0.052***
Rank of education in years	0.003	0.038***	0.040***	0.005	0.003***	0.020***	0.023***
Rank of income	0.000	0.061***	0.064***	0.021***	0.031***	0.028***	0.041***
Rank of financial wealth	0.000	-0.033***	-0.035***	0.011***	-0.029***	-0.024***	-0.012***
# of observations	502,304	502,304	254,291	248,013	180,062	321,615	125,577

Table 4: Cross-sectional Variation in Incentives

The percentiles of the distribution reported in the column headings are calculated across our sample of all stable households in Denmark with a fixed rate mortgage, pooling data over 2010 and 2011, or separately by years. The blocks of statistics refer to interest rate spread in percentage points (defined as the coupon rate on the old mortgage less the yield on a new mortgage), Threshold Level in percentage points (calculated using the second order approximation Agarwal et al. (2013) formula,) and incentives in percentage points (measured as the interest rate spread less the threshold level). Within each block of statistics, percentiles are calculated for all households, and separately for the sub-populations of refinancing and non-refinancing households.

	Min	*1%*	*5%*	*10%*	*25%*	*Median*	*75%*	*90%*	*95%*	*99%*	*Max*
						Interest Rate Spread in Percentage Points					
All	-1.20	-1.20	-0.20	-0.20	0.10	0.80	1.10	1.80	2.10	2.80	6.80
2010	-1.20	-1.20	-0.20	-0.20	-0.20	0.80	0.80	1.80	1.80	2.80	6.80
2011	-0.90	-0.90	0.10	0.10	0.10	1.10	1.10	1.10	2.10	3.10	6.10
						Threshold Level in Percentage Points					
All	1.03	1.17	1.23	1.28	1.38	1.56	1.81	2.17	2.48	3.10	4.51
2010	1.03	1.17	1.23	1.28	1.39	1.56	1.81	2.17	2.48	3.10	4.51
2011	1.04	1.17	1.23	1.28	1.38	1.55	1.81	2.17	2.48	3.11	4.48
						Incentives in Percentage Points					
All	-5.38	-3.62	-2.34	-1.95	-1.55	-0.98	-0.49	-0.14	0.37	0.88	3.93
2010	-5.27	-3.72	-2.43	-2.04	-1.66	-0.90	-0.55	0.08	0.43	1.09	3.69
2011	-5.38	-3.44	-2.25	-1.80	-1.43	-1.12	-0.41	-0.18	0.16	0.81	3.93

Table 5: Errors of Commission and Omission

The panel reports the error of commission and error of omission across level of error thresholds. Error of commission is the fraction of individuals with incentives < -threshold level who refinances. Error of omission is the fraction of individuals with incentives > threshold who do not refinance. Level of error thresholds varies from 0 percentage points to 1.5 percentage points.

	Level of Error Threshold					
	0	0.25	0.5	0.75	1	1.5
Error of commission	0.041	0.040	0.035	0.026	0.021	0.021
# of observations	460,831	435,232	373,707	295,455	240,445	137,191
Error of omission	0.635	0.584	0.603	0.683	0.601	0.713
# of observations	41,473	31,550	16,165	6,681	4,326	1,247

Table 6: Characteristics of Commission and Omission Errors

The average characteristics for individuals with incentives above and below thresholds of 0 and 0.25 percentage points depending on whether the household refinance or did not refinance their mortgage. Error of commission occurs for households with incentives below the threshold who refinances. Error of omission occurs for households with incentives above the threshold who do not refinance. The rows describe the characteristics; single households (male or female) are defined as households with only one adult living at the address. "Married" households are defined as households with two legally bound adults (which includes registered partnership of same-sex couples). "Children in family" is an indicator for households with resident children. Metropolitan is an indicator for households living in greater Copenhagen. "Getting married" is an indicator which indicates a change in marital status over the sample period. "Having Children" is an indicator for households having their first child. "Rank of Age" is the rank of the age of the oldest person living in the household. "Rank of Education" is the rank of the best educated individual in the household. "Rank of Income (financial wealth)" is the rank of the total income (financial wealth) of the household. All rank variables are normalized such that they take values between -0.5 and 0.5.

	Threshold = 0				**Threshold = 0.25**			
	Incentives < Threshold		*Incentives > threshold*		*Incentives < Threshold*		*Incentives > threshold*	
	Refinance	*No Refinance*	*Refinance*	*No Refinance*	*Refinance*	*No Refinance*	*Refinance*	*No Refinance*
Single male household	0.199	0.095	0.091	0.129	0.189	0.083	0.090	0.131
Single female household	0.175	0.097	0.095	0.125	0.162	0.083	0.093	0.127
Married household	0.513	0.653	0.712	0.646	0.525	0.673	0.714	0.644
Children in family	0.314	0.516	0.455	0.394	0.351	0.552	0.452	0.385
Metropolitan property	0.121	0.128	0.123	0.128	0.135	0.138	0.120	0.124
Getting married	0.012	0.025	0.016	0.012	0.014	0.027	0.015	0.011
Change to health	0.109	0.101	0.102	0.109	0.111	0.103	0.102	0.108
Having children	0.030	0.062	0.043	0.033	0.036	0.069	0.042	0.031
Demeaned rank of:								
Age	0.007	-0.114	-0.018	0.004	-0.019	-0.134	-0.016	0.010
Length of education	-0.069	0.039	0.027	0.005	-0.053	0.058	0.024	0.000
Income	-0.105	0.062	0.040	0.002	-0.082	0.091	0.038	-0.004
Financial wealth	-0.025	-0.067	0.013	0.003	-0.040	-0.074	0.014	0.006
# of observations	26,355	15,118	18,699	442,132	18,440	13,110	17,378	417,854

Table 7: Refinancing: Simple Probit Specifications

This table shows results from simple probit specifications which seek to uncover the determinants of refinancing. The dependent variable takes the value of 1 if a household refinances in a given year, and 0 otherwise. Model 1 estimates a probit, with no non-linear transformations of the independent variables. Models 2 and 3 include non-linear transformations, f(x), of several of the rank control variables in addition to their levels; in Model 2, $f(x) = |x|$; and in Model 3, $f(x) = (\sqrt{2}x)^2$. The entire sample of stable households in Denmark with a fixed rate mortgage and possible refinancing decisions in 2010 and 2011 is used to estimate these specifications. The independent variables are indicated in the rows, with the 8 variables representing dummies for the demographic status indicated in the row headers. The next four variables are normalized to take values between 0 and 1, and range between -0.5 and 0.5 once demeaned. All variables are described in the header to Table 3. ***, **, and * indicate coefficients that are significant at the one, five, and ten percent level, respectively, using standard errors clustered at the municipality and year level.

	Model 1	*Model 2*	*Model3*
Single male household	-0.187***	-0.149***	-0.155***
Single female household	-0.110***	-0.079***	-0.085***
Married household	0.012	0.012	0.011
Children in family	0.003	0.014	0.014
Metropolitan property	-0.014	-0.008	-0.006
Getting married	0.107***	0.100***	0.103***
Change to health	-0.039***	-0.043***	-0.043***
Having children	0.079***	0.068***	0.070***
Demeaned rank of:			
Age	-0.328***	-0.270***	-0.273***
Length of education	0.064**	0.070***	0.072***
Income	0.033	0.145***	0.130***
Financial wealth	-0.025*	-0.037***	-0.037**
Non-linear transformation f(x),where x is the demeaned rank of:			
Age		0.182***	0.133***
Length of education		-0.009	0.011
Income		-0.209***	-0.205***
Financial wealth		-0.365***	-0.350***
Constant	-1.480***	-1.395***	-1.425***
Pseudo R^2	0.0106	0.0125	0.0124
Log Likelihood	-122588.15	-122347.68	-122359.97
# of observations	502,304	502,304	502,304

Table 8: Refinancing: Heterogeneous Baseline with Constant Attention, and Heterogeneous Attention with Constant Baseline

In these specifications, the dependent variable continues to take the value of 1 for a refinancing in 2010 or 2011, and 0 otherwise, using the same sample as in Table 5. In columns 1, 3, and 5, we estimate a simple "Baseline" probit specification as in Table 4, but with the addition of "Incentives", which are measured using the Agarwal et al. (2013) formula. This approach calculates refinancing incentives as the difference between the annuitized option value of taking on the new mortgage, less the interest paid on the old mortgage. Columns 2, 4, and 6 estimate a specification in which these incentives are interacted with an "attention" function, holding fixed a baseline probability of refinancing. The level of attention is calculated by the function $A(\Delta's) = \exp(\Delta's)$, where Δ is the vector of estimated coefficients on the covariates in the vector *s*, reported in the rows, and the same set of covariates as described in Table 3. As before, Models 2 and 3 include non-linear transformations, f(x), of several of the rank control variables in addition to their levels; in Model 2, $f(x) = |x|$; and in Model 3, $f(x) = (\sqrt{2}x)^2$. Pseudo R^2 is calculated using the formula $R^2 = 1 - L_1/L_0$, where L_1 (L_0) is the log likelihood from the unconstrained (constrained constant only) model. ***, **, and * indicate coefficients that are significant at the one, five, and ten percent level, respectively, using standard errors clustered at the municipality and year level.

	Model 1		**Model 2**		**Model 3**	
	Baseline Probability	*Attention*	*Baseline Probability*	*Attention*	*Baseline Probability*	*Attention*
Constant	-1.031***	-1.031***	-0.841***	-1,029***	-0.905***	-1.029***
Single male household	-0.164***	0.003***	-0.145***	0.054**	-0.151***	0.071***
Single female household	-0.106***	0.122***	-0.089***	0.158***	-0.096***	0.174***
Married household	0.059***	-0.107***	0.052***	-0.082***	0.050***	-0.073***
Children in family	0.012	-0.027	0.012***	0.004	0.011	0.008
Metropolitan property	-0.076	0.105***	-0.063***	0.072***	-0.060	0.070***
Getting married	0.041*	0.123**	0.049**	0.067	0.054**	0.049
Change to health	-0.063***	0.077***	-0.061***	0.056***	-0.060***	0.052***
Having children	0.035**	0.106***	0.043***	0.031	0.048***	0.018
Demeaned rank of:						
Age	-0.142***	-0.244***	-0.100***	-0.213***	-0.105***	-0.204***
Length of education	0.034	0.205***	0.069***	0.124***	0.067	0.132***
Income	0.076***	0.227***	0.152***	0.280***	0.137***	0.312***
Financial wealth	0.134***	-0.458***	0.123***	-0.428***	0.122***	-0.421***
Non-linear transformation f(x), x is the demeaned rank of:						
Age			-0.010	0.620***	-0.057**	0.668***
Length of education			-0.132***	0.239***	-0.094***	0.205***
Income			-0.211***	0.090**	-0.205***	0.025
Financial wealth			-0.429***	0.452***	-0.416***	0.397***
Incentives (Intercept in Attention Function)	-0.430***	-0.378***	-0.426***	-0.620***	-0.425***	-0.620***
Pseudo R^2	0.007	0.008	0.010	0.011	0.010	0.011
Log Likelihood	-106753.91	-106671.67	-106482.51	-106393.91	-106471.77	-106372.84
Observations	502,304	502,304	502,304	502,304	502,304	502,304

Table 9: Heterogeneous Baseline with Heterogeneous Attention

In these specifications, the dependent variable continues to take the value of 1 for a refinancing in 2010 or 2011, and 0 otherwise, using the same sample as in Table 5. This table shows the results of estimating three models (Models 1, 2, and 3). In each model, we allow for heterogeneous baseline probabilities of refinancing, conditional on household attributes (the first column under each model), as well as heterogeneous attention to incentives (the second column under each model). As before, "Incentives" are measured using the Agarwal et al. (2013) formula, which calculates refinancing incentives as the difference between the annuitized option value of taking on the new mortgage, less the interest paid on the old mortgage. The level of attention is calculated by the function $A(\Delta's) = \exp(\Delta's)$, where Δ is the vector of estimated coefficients on the covariates in the vector *s*, reported in the rows, and the same set of covariates as described in Table 3. As before, Models 2 and 3 include non-linear transformations, f(x), of several of the rank control variables in addition to their levels; in Model 2, $f(x) = |x|$; and in Model 3, $f(x) = (\sqrt{2}x)^2$. Pseudo R^2 is calculated using the formula $R^2 = 1 - L_1/L_0$, where L_1 (L_0) is the log likelihood from the unconstrained (constrained constant only) model. ***, **, and * indicate coefficients that are significant at the one, five, and ten percent level, respectively, using standard errors clustered at the municipality and year level.

	Model 1		**Model 2**		**Model 3**	
	Baseline Probability	*Attention*	*Baseline Probability*	*Attention*	*Baseline Probability*	*Attention*
Single male household	-0.158***	-0.113***	-0.130***	-0.044	-0.134***	-0.029
Single female household	-0.036	0.130***	-0.014***	0.186***	-0.017	0.200***
Married household	0.057***	-0.040	0.052***	-0.031***	0.052***	-0.025
Children in family	0.034**	-0.006	0.044***	0.035	0.045***	0.043**
Metropolitan property	-0.071	0.030	-0.061	0.021	-0.058	0.021
Getting married	0.058	0.094	0.060	0.066	0.063***	0.053
Change to health	-0.062***	0.007	-0.067***	-0.012	-0.065***	-0.014
Having children	0.054***	0.092***	0.050***	0.047	0.053***	0.039
Demeaned rank of:						
Age	-0.350***	-0.706***	-0.256***	-0.502***	-0.251***	-0.477***
Length of education	0.146***	0.366***	0.160***	0.288***	0.161***	0.289***
Income	0.291***	0.565***	0.389***	0.699***	0.378***	0.727***
Financial wealth	-0.024	-0.460***	-0.036***	-0.473***	-0.040	-0.477***
non-linear transformation f(x), x is the demeaned rank of:						
Age			0.155***	0.594***	0.104***	0.612***
Length of education			-0.062	0.163**	-0.027	0.172***
Income			-0.237***	-0.205***	-0.244***	-0.263***
Financial wealth			-0.479***	-0.079	-0.479***	-0.112
Constant baseline probability	-1.071		-0.921***		-0.969***	
Constant attention		-0.466***		-0.595***		-0.551***
Pseudo R^2		0.024		0.027		0.028
Log Likelihood		-104939.33		-104939.33		-104559.77
# of observations		502,304		502,304		502,304

Table 10: Test of Proportionality of Baseline and Attention

In these specifications, the dependent variable continues to take the value of 1 for a refinancing in 2010 or 2011, and 0 otherwise, using the same sample as in Table 6. This table shows the results of estimating two models (Models 1 and 3). In each model we estimate two separate models: (i) a constrained model where all coefficients in the attention functions are identical to a proportion of the coefficients in the baseline probability function, (ii) an unconstrained model where this is not the case. The columns deviation shows the difference in coefficients in the constrained and unconstrained model. We allow for heterogeneous baseline probabilities of refinancing, conditional on household attributes (the first column under each model), as well as heterogeneous attention to incentives (the second column under each model). As before, "Incentives" are measured using the Agarwal et al. (2013) formula, which calculates refinancing incentives as the difference between the annuitized option value of taking on the new mortgage, less the interest paid on the old mortgage. The level of attention is calculated by the function $A(k\Delta's) = \exp(k\Delta's)$, where Δ is the vector of estimated coefficients on the covariates in the baseline probability of refinancing, reported in the rows, and the same set of covariates as described in Table 3. As before, Model 3 include non-linear transformations, f(x), of several of the rank control variables in addition to their levels where $f(x) = (\sqrt{2}x)^2$. ***, **, and * indicate coefficients that are significant at the one, five, and ten percent level, respectively, using standard errors clustered at the municipality and year level.

	Model 1				**Model 3**			
	Baseline Probability	*Deviation*	*Attention*	*Deviation*	*Baseline Probability*	*Deviation*	*Attention*	*Deviation*
Single male household	-0.147***	0.012	-0.282***	-0.169	-0.098***	0.036	-0.183***	-0.154
Single female household	-0.002	0.034	-0.003	-0.134	0.039**	0.056	0.073**	-0.127
Married household	0.003	-0.054	0.005	0.045	0.007	-0.045	0.013	0.038
Children in family	-0.001	-0.035	-0.003**	0.003	0.019**	-0.027	0.035**	-0.009
Metropolitan property	-0.010	0.061	-0.019	-0.049	-0.008	0.050	-0.015	-0.036
Getting married	0.050***	-0.008	0.096**	0.002	0.035*	-0.028	0.065*	0.012
Change to health	-0.021**	0.041	-0.041	-0.048	-0.031***	0.034	-0.059***	-0.045
Having children	0.053***	-0.001	0.102***	0.010	0.037***	-0.016	0.069***	0.030
Demeaned rank of:								
Age	-0.365***	-0.015	-0.703***	0.003	-0.276***	-0.025	-0.516***	-0.039
Length of education	0.187***	0.041	0.360***	-0.005	0.176***	0.015	0.330***	0.041
Income	0.273***	-0.018	0.526***	-0.039	0.395***	0.017	0.739***	0.012
Financial wealth	-0.178***	-0.155	-0.344***	0.116	-0.197***	-0.157	-0.368***	0.108
non-linear transformation f(x), x is the demeaned rank of:								
Age					0.242***	0.138	0.453***	-0.159
Length of education					0.057**	0.084	0.107***	-0.065
Income					-0.205***	0.038	-0.384***	-0.120
Financial wealth					-0.193***	0.286	-0.361***	-0.250
Constant	-1.044***		-0.473***		-1.047***		-0.477***	
Coefficient of Proportionality	1.927***				1.870***			
Chi^2	917.76				1464.25			
Likelihood ratio test p-value	0.000				0.000			

Figure 1: Interest Rate of 30-Year FRM

Figure 2: Refinancing Probability

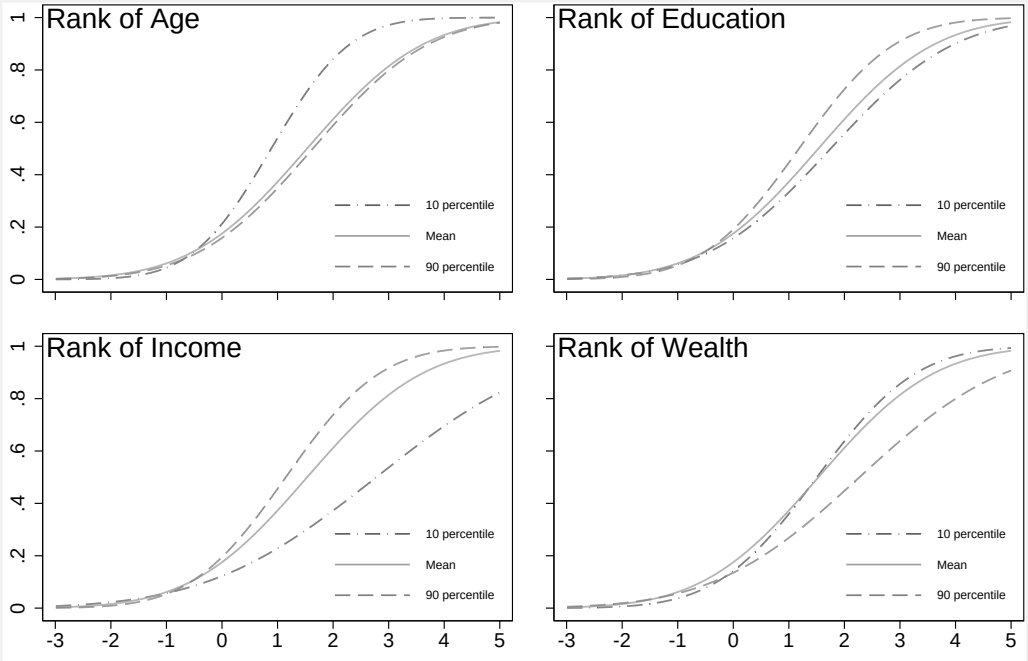

Figure 3: Inattention and Inertia