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Why Do Borrowers Make Mortgage Refinancing Mistakes?

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Abstract

Refinancing a mortgage is often one of the biggest and most important financial decisions that people make. Borrowers need to choose the interest rate differential at which to refinance and, when that differential is reached, they need to take the steps to refinance before rates change again. The optimal differential is where the interest saved by refinancing equals the sum of refinancing costs and the option value of refinancing. Using a unique panel data set, we find that approximately 59% of borrowers refinance sub-optimally – with 52% of the sample making errors of commission (choosing the wrong rate), 17% making errors of omission (waiting too long to refinance), and 10% making both errors. Financially sophisticated borrowers make smaller mistakes, refinancing at rates closer to the optimal rate and waiting less after mortgage rates reach the borrowers' trigger rates. Evidence suggests borrowers learn from their refinancing experiences as they make smaller mistakes on their second refinancing than on their first one.

Keywords: Household Finance, Mortgages, Refinance, Option Value, Financial Crisis, Rational Inattention

JEL classification: G11, G21

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1. Introduction

Refinancing a mortgage is as American as apple pie. Over the period 2000–09, Americans took out 52 million mortgages to finance the purchase of new homes, but 71 million to refinance existing mortgages (henceforth, refis).[1] That is, there were 1.4 refis for every mortgage for a home purchase. Given that purchasing a home is generally the biggest financial decision a household makes, that makes the choice of when to refinance a major event for most households (Campbell, 2006). Research suggests that people often make poor financial decisions (Campbell, Jackson, Madrian, and Tufano, 2011). We explore whether this is true for refis as well. As we describe next, much of the existing literature focuses on whether people leave money on the table (Choi, Madrian, and Laibson, 2011) – what we call an error of *commission*. But, as we show here, during the refinancing process, households also make errors of *omission* – that is, by failing to refinance at the optimal time. When thinking about the costs of sub-optimal financial decision-making, it is important to focus on both errors of commission and errors of omission.[2]

Research on errors of commission suggests that consumers often make financial mistakes. For example, many individuals do not hold checking accounts (Hilgert et al., 2003) or take out payday loans at astronomical interest rates when cheaper forms of credit are available (Agarwal, Skiba, and Tobacman, 2009). More broadly, it is puzzling that less than 30 percent of U.S. households directly participate in equity markets (Cole and Shastry, 2009; Li, 2012) and among those who do hold stocks, many have highly concentrated portfolios and trade excessively (Korniotis and Kumar, 2011).

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[1] These numbers are based on the authors' calculations from data that mortgage lenders are required to file under the Home Mortgage Disclosure Act (HMDA).

[2] The cost of a suboptimal decision for mortgage of $200,000 with an interest rate differential of 200 basis points can be a few thousand dollars – a substantial fraction of the homeowner's disposable income (Agarwal, Driscoll, and Laibson, 2012).

Household decisions that are suboptimal have potentially important effects on individual welfare. There also can be significant social ramifications arising from poor financial decision-making. The sharp decline in housing markets and the associated rise in mortgage defaults surrounding the recent financial crisis in the United States arguably were due, at least to some degree, to poor financial decision-making behavior by some households. Despite the growing salience of the issue of household financial decision-making, our current understanding of exactly how individuals make their financial decisions is limited.

We examine mistakes in mortgage refinancing. The decision to refinance a mortgage optimally requires solving a complicated system of partial differential equations.[3] This can prove to be problematic because significant cognitive ability often is needed to properly make optimal financial choices (Agarwal and Mazumder, 2013). The complexities in determining the optimal time to refinance lead many, including financial advisors, to rely on rules of thumb, that is, simplified solutions. Often, for example, financial advisers advocate the use of a net present value (NPV) rule that says borrowers should refinance their mortgages when the net present value of the interest saved exceeds the cost of refinancing. This rule ignores the potentially large loss in value from exercising the option to refi today rather than in the future (Agarwal, Driscoll, and Laibson, 2012). This paper explores how errors in refinancing are related to borrower characteristics.

Refinancing a mortgage requires not only that a borrower select an interest rate at which she is willing to refinance, but that she take the actions necessary to refi (such as contacting a broker or bank and completing paperwork). Agarwal, Driscoll, and Laibson (2012) argue that borrowers do not actively monitor mortgage rates and, even if they notice that the mortgage rate has reached their "trigger rate" for refinancing optimally, they may not immediately refi because

[3] See Dunn and McConnell (1981a, 1981b), Dunn and Spatt (2005), and Hendershott and Van Order (1987).

they are too busy. These errors of omission have been examined for other decisions (e.g., Agarwal et al., 2007 and Korniotis and Kumar; 2011). Some delay may be the optimal response for busy borrowers – what some refer to as rational inattention (e.g., Sims, 2003; Reis, 2006). We show that many borrowers do not refinance immediately when their trigger rate is reached, and discuss whether this may reflect rational inattention or a more costly form of distraction.

To most clearly show the relationship between refinancing mistakes and borrower characteristics, we focus on borrowers who refinance in order to reduce mortgage payments. Our sample does not include borrowers who refinance in order to extract equity from their homes – a common practice that can be used to increase current consumption (Greenspan and Kennedy, 2008; Hurst and Stafford, 2004). When borrowers want to use their homes as a "piggy bank" this way, it changes the way they should think about when to refinance.[4] For this reason, we exclude refis where borrowers extract equity from our analysis.

Using a unique sample of people who choose to refi during 1998–2011, we find that 52% of refinancers do so at a rate that was at least 50 basis points from what we estimate as the optimal refi rate for that borrower (errors of commission) and about 17% of borrowers waited at least six months or longer before they refinanced (errors of omission). Overall, 59% of refinancers make at least one error, while 10% make both errors. Most borrowers, including those who make large mistakes, refinance at a rate differential that is too small, that is, when the interest rate on the refinanced mortgage is not sufficiently below the initial mortgage rate.

We show that the errors of commission in choosing the refinancing rate and of omission in the timing of refinancing are correlated with borrower sophistication. Smaller mistakes are associated with borrowers having larger FICO credit scores and higher income – variables that

[4] See, Dunn and McConnell (1981a, 1981b), Dunn and Spatt (2005), Hendershott and Van Order (1987), Chen and Ling (1989), Follain, Scott, and Yang (1992), Yang and Maris (1993), Stanton (1995), Longstaff (2004), and Deng and Quigley (2006).

are correlated with the level of financial sophistication (Amromin et al., 2011). More sophisticated borrowers refinance at interest rates closer to their respective optimal refinancing rate and spend less time with the average mortgage rate below that optimal rate before they refinance their initial mortgage. We confirm that borrowers also make smaller mistakes when mortgages are more important to them (as measured by the ratio of the mortgage size to the borrower's income).

Our paper is broadly related to the growing literature that finds evidence linking the creation of the real estate bubble in the early 2000s to misaligned incentives of intermediaries and individuals - e.g., Keys, Mukherjee, Seru, and Vig (2010), Ben-David (2011), and Jiang, Nelson, and Vytlacil (2012).

The rest of the paper is organized as follows. In section 2, we review the literature, and in section 3, we provide a description of the data we use. The main results are presented in section 4. Finally, we present our conclusions in section 5.

2. Literature Review

Refinancing has long been of interest to both practitioners and researchers interested in the valuation of mortgage-backed securities and researchers interested in consumer choice. Dickinson and Heuson (1994) and Kau and Keenan (1995) provide extensive surveys.

There is an extensive literature deriving the optimal time for a borrower to refinance. The initial work in this area used continuous time option valuation models (Dunn and McConnell, 1981a, 1981b). Later papers relaxed some of the assumptions of the early models, such as by allowing borrowers to endogenously choose to default (Hendershott and Van Order, 1987).[5] These papers implicitly solved for the optimal refinancing differentials as solutions to partial differential equations, which were evaluated numerically. Finally, Agarwal, Driscoll, and Laibson (2012; henceforth, ADL) derived a closed-form solution for the optimal interest rate at which to refinance.[6] We use the ADL model to derive the optimal refi rate used in our paper.

It soon became apparent that borrower behavior deviated in significant ways from the predictions of the models described in these papers. As we describe here, there can be many reasons why borrowers refinance when the rate differential is too small. However, participants in the mortgage-backed securities industry had long noticed that some consumers did not refinance even after very large drops in mortgage rates. The failure of this group to exercise "in the money" options led them to be labeled "woodheads." Some borrowers exhibited the opposite problem: They refinanced even when rates had risen. These discrepancies were picked up in estimates of the hazard rates of default (Green and Shoven, 1986; Schwartz and Torous 1989, 1992, 1993; Giliberto and Thibodeau, 1989; Richard and Roll, 1989).

To resolve these puzzle, some researchers, as reported in their studies, added additional complexity to the option-pricing model to address the issues raised in the previous paragraph. Archer and Ling (1993) add heterogeneity in transaction costs. Stanton (1995) adds both heterogeneity in transaction costs and an exogenous probability of prepayment. Downing, Stanton, and Wallace (2005) allow variations in housing price to affect prepayment of mortgages. In hazard rate estimates of prepayment of mortgages, LaCour-Little (1999) and

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[5] See also Dunn and Spatt (2005), Chen and Ling (1989) and Follain, Scott and Yang (1992).

[6] ADL (2012) compare their interest rate differentials with those computed numerically by Chen and Ling (1989), who do not make many of our simplifying assumptions. They find that the two approaches generate recommendations that differ by fewer than 10 basis points. Moreover, Follain, Scott, and Yang (1992) characterize the differentials they derive as implying "that the commonly used 'rule of thumb'—refinance if the interest rate declines by 200 basis points—is a fair approximation."

Bennett, Peach, and Peristiani (2000, 2001) find that refinancing depends on borrower-specific characteristics.

Several researchers, including Hurst (1999) and Hurst and Stafford (2004), have empirically examined refis for consumption smoothing purposes. A borrower can use a refi to smooth consumption by cashing out some of the home equity as part of the process. We do not want to examine refinancings where consumption smoothing plays a major role, so we restrict our attention to refis where there is at most minimal equity cash out.

LaCour-Little (1999) distinguishes among various sources of prepayment – for example, borrower mobility, liquidity demand, and interest-rate-driven rate-term refinancing – using a loan-level data set that provides "pure" refinancing behavior as opposed to "general" prepayment behavior. After excluding prepayments that might be for reasons other than a reduction in expected interest payments, LaCour-Little (1999) concludes that borrower and loan characteristics are significant factors driving prepayment behavior. This finding is especially true if the option is "at the money" as opposed to "in the money" or "out of the money." Bennett, Peach, and Peristiani (2000) simulate the threshold at which individuals will refinance a mortgage loan conditional not only on the market conditions but also on individual borrower characteristics. For example, they predict that a person with good credit history and 70% loan-to-value ratio could refinance at an interest rate differential of 70 basis points to 140 basis points. We extend the approach in LaCour-Little (1999) by examining the relationship between the decision to refinance and characteristics of borrowers and loans.

There is a missing piece to many of the analyses discussed thus far: Borrowers often wait too long to refinance. Stanton (1995) develops a model of mortgage prepayment where mortgage holders face heterogeneous transaction costs. The model indicates that mortgage holders act as though the transaction costs far exceed the explicit costs incurred in refinancing. Stanton (1995) finds that mortgage holders typically delay refinancing for more than a year beyond the optimal refinancing date.

An alternative reason why borrowers may delay refinancing is that they do not always monitor mortgage rates closely. Borrowers are faced daily with many complicated, time-consuming choices. Given a binding time-budget constraint, distracted borrowers may only be able to make certain decisions at stochastic intervals – or, put less formally, when they have a spare moment. The idea that people may only make decisions infrequently has long been used by economists to explain apparent deviations from optimal behavior. Calvo (1983) modeled monopolistically competitive firms as setting prices at some constant hazard rate, generating price stickiness; a version of this model is now the basis for the commonly used New Keynesian aggregate supply curve. Gabaix and Laibson (2001) show that the assumption that agents can only adjust infrequently helps explain the equity premium puzzle. Mankiw and Reis (2002) alter that model by assuming that price-setters can change prices continuously, but are only able to gather information at random intervals, generating persistence in inflation; Ball, Mankiw, and Reis (2003) use this framework to study monetary policy. There is reason to believe that inattention can be a rational response for busy agents (Sims, 2003; Reis, 2006).[7]

The actual behavior of mortgage holders sometimes differs from the predictions of the optimal refinancing model. In the 1980s – when mortgage interests rates fell – some borrowers failed to refinance despite holding options that were deeply "in the money" (Giliberto and Thibodeau, 1989). On the other hand, Chang and Yavas (2009) have noted that some borrowers

[7] Inertia in economic decisions is consistent with investors rationally splitting their limited attention across different information streams (Sims, 2003; Reis, 2006). There is also empirical evidence of inattention (whether rational or not) in financial markets. For example, there is evidence that investors respond less to earnings announcements (and possibly other news announcements) that are made on Fridays (DellaVigna and Pollet, 2009). In addition, investors tend to be net buyers of stocks that are in the news more (Barber and Odean, 2008).

refinanced too early during the period 1996–2003.[8] Agarwal, Ben-David, and Yao (2012) document that some borrowers exhibit the sunk cost fallacy in their mortgage refinancing behavior.

3. Data

The mortgage data in this study are derived by matching the first and second mortgage origination of the same borrower. The data consists of first-lien prime mortgages that are securitized by Fannie Mae or Freddie Mac. The data are unique and have several advantages. First, we use a precise match using the Social Security number of a borrower as well as the property's address; matching the mortgages in this way circumvents any noise due to a fuzzy matching process using a series of variables. Second, we know why the borrowers refinance their mortgages. This allows us to focus on refis aimed toward lowering mortgage payments. Third, we know if the borrowers refinanced their mortgages multiple times. This is important because borrowers can make mistakes in their first refinancing decisions but then learn from their mistakes and change their behavior.[9]

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[8] Many papers document and attempt to explain the puzzling behavior of mortgage holders. See Green and Shoven (1986); Schwartz and Torous (1989,1992, 1993); Giliberto and Thibodeau (1989); Richard and Roll (1989); Archer and Ling (1993); Stanton (1995); LaCour-Little (1999); Bennett, Peach, and Peristiani (2000, 2001); Hurst (1999); Downing, Stanton, and Wallace (2005); and Hurst and Stafford (2004).

[9] The results of our analysis are similar when we use a data set derived with a fuzzy matching process using a series of variables—more specifically, a matched data set derived from data that mortgage originators are required to report under the Home Mortgage Disclosure Act and a large proprietary data set from LPS (Lender Processing Services) Applied Analytics. That is, we use a dual matching process on the HMDA and LPS data to generate a matched data set. The HMDA and LPS data contain information on borrower characteristics at the time a mortgage is issued. The LPS data also has information on the payment history of a mortgage. However, neither data set directly ties a mortgage used to refinance a house (a "refi" mortgage) with the borrower's prior mortgage that is repaid using the refi. To get this information, we match mortgages that are repaid with refi loans based on a number of mortgage and borrower characteristics. Note that while we can match mortgages, we cannot identify borrowers so the matches are subject to error. We are able to identify 32,000 instances of an initial mortgage and an associated refinancing. However, unlike with the data used in this paper, we have very few borrowers for whom we can identify a string of three mortgages on the same property. While the results from the HMDA–LPS sample are not reported in the paper, they are available upon request.

Standard residential mortgages in the United States – including those in our sample – offer borrowers the ability to prepay at any time without penalty. One way to prepay a mortgage is to refinance it, with the proceeds of the new loan being used to pay the original one. A primary reason for refinancing like this is to reduce the monthly payments on a mortgage. For example, a borrower that refinances from a 7% mortgage into a 6% mortgage will save 1% on the interest costs for the life of the mortgage. Yet, there is another way a refi can help a borrower. A refi can improve borrower liquidity, either by providing cash as part of the refi or by reducing mortgage payments. In a substantial share of mortgages, borrowers convert some of their home equity to cash (the so-called cash-out refis).[10] In order to focus on the expected payment reduction, we drop cash-out refis from our sample.

For a refinancing to be in our sample, both the mortgage that is being refinanced and the refi had to be originated during the period 1998–2011. In addition, in order to make the interest rate comparisons as straightforward as possible, we confine our sample to observations where both the initial mortgage and the refi are 30-year fixed-rate mortgages (FRMs) and where the refi does not include a cash-out. In addition, we drop the handful of observations where the refi rate is either more than one percentage point higher or more than four percentage points lower than the original (that is, previous) mortgage rate.[11] This leaves us with a sample of 271,216 refis, of which 4,882 are second refis (see Table 1 for summary statistics for our sample).[12]

[10] In addition, a refi – even one that does not involve a cash out – can improve liquidity by extending the maturity of the debt. Since we include only observations where a 30-year fixed-rate mortgage (FRM) is refinanced with another 30-year FRM, borrowers will be extending the maturity of their mortgages for all the refis in our sample. This means that the monthly payment on the refi can be lower than the payment on the initial mortgage even if the interest rate does not change or rises. Thus, borrowers can improve liquidity even with refis that increase the mortgage rate. (As discussed in the appendix, by construction, all refis in our sample have a lower monthly payment than the mortgages they replace.) We expect that this kind of liquidity enhancement plays a minor role in the decision to refinance, but we discuss this further later in the paper.

[11] We drop refis where the refi rate is more than one percentage point above the initial mortgage rate because these refis could be driven by other non-interest-saving motives. Our results are not sensitive to this choice.

[12] We drop the small number of third and fourth refis from our sample. All results are robust to their inclusion.

4. Hypothesis and Results

We measure the economic value of the reduction in payments using the mortgage interest rate change from the initial mortgage to the refi. Let $\Delta rate$ be the refi rate differential, that is, the difference between the refi and initial mortgage rates, with a negative value for $\Delta rate$ indicating that the refi rate is lower than the initial rate.[13] In our sample, borrowers save an average of 121 basis points (1.21 percentage points) on their mortgage when they refi (Table 1). But there is a wide distribution in $\Delta rate$ in the sample (Panel A of Figure 1). Many borrowers refi when the rate differential is 25 basis points or less, while others do not refi until the rate differential exceeds 200 basis points. To examine whether these borrowers are making mistakes, we need to ask when it is optimal to refinance.

In deciding whether to refinance, a borrower must trade off the gains from refinancing against the costs of doing so. The borrower incurs the cost of refinancing (direct and indirect cost), which is why the optimal rate at which a borrower should refinance is strictly less than the rate on the borrower's existing mortgage. Determining when the option to refinance is "in the money" is a complicated function of factors, including the remaining maturity of the initial mortgage and the expected path of future interest rates. We follow ADL (2012) to estimate the optimal refinance rate or, equivalently, the optimal refi rate differential. Their model depends on the discount factor, closing costs, mortgage size, the marginal tax rate, the standard deviation of the innovation in the mortgage interest rate, and the Poisson rate of exogenous real repayment. In the appendix, we derive the optimal refinancing rate for each borrower by using the ADL approach. On average, the borrowers in our sample should have refinanced at an interest rate

[13] All interest rates are adjusted for points where points are an upfront payment to a lender intended to reduce the interest rate on a mortgage.

that was 158 basis points lower than the original (or previous) mortgage's interest rate; however, on average, they in fact refinanced at an interest rate that was only 121 basis points lower (Table 1).

The difference between the optimal refi rate and the actual refi rate suggests that most borrowers do not solve a complex optimal refinancing rate model prior to making their refinancing decisions. As an alternative, borrowers may adopt a rule of thumb (see, Follain, Scott, and Yang, 1992). The rule of thumb for an individual borrower may be a simplified solution to the full model, or it may come from somewhere else such as advice from a friend or a mortgage broker. A "rule-of-thumb" borrower will refinance when she notices that the mortgage rate is at or below her rule-of-thumb trigger rate. It is likely that more financially sophisticated borrowers have more accurate rules of thumb. We refer to errors in the rate at which a borrower refinances as *errors of commission*.

To see how close borrowers come to refinancing optimally, whether by solving for the optimal refi rate or using a rule of thumb, let

$$\textit{optimal refi rate differential} = \textit{optimal refi rate} - \textit{initial mortgage rate},$$

and

$$\begin{aligned} \textit{refi error} &= |\,\Delta \textit{rate} - \textit{optimal refi rate differential}\,| \\ &= |\,\textit{actual refi rate} - \textit{optimal refi rate}\,| \end{aligned}$$

where the *optimal refi rate* comes from our model based on ADL. In the figures, we sometimes use

$$\textit{signed refi error} = \textit{actual refi rate} - \textit{optimal refi rate}$$

(that is, *refi error* without the absolute value operator). Panel B of Figure 1 gives the distribution for *signed refi error* in our sample. About 48% of borrowers refinance within 50 basis points of the optimal rate. We say that these borrowers refinanced in the optimal range. Most of those who refi outside the optimal range choose a rate that, while lower than the rate on their existing mortgage, is not different enough to make up for the costs of refinancing, including the forgone option to refi if rates fall slightly in the future. Only a few borrowers end up refinancing at a rate that is below the rate on their initial mortgage by more than the optimal amount. Of course, we do not capture the nearly half of borrowers that have never refinanced, although rates have fallen sufficiently (Fannie Mae, 2012).

There is a second part to the refinancing decision. Borrowers must not only decide what the trigger mortgage rate for refinancing is; they must also start the refinancing process by contacting a bank when the rate is at or below the trigger rate.[14] This may not happen immediately if the borrowers do not pay careful attention to mortgage rates and thus they may miss opportunities to refinance when the mortgage rate first hits the trigger rate. Inattentive or distracted borrowers might only monitor mortgage rates periodically or when they receive another signal that indicates a potential drop in rates. Rational inattention could explain delays of several months in refinancing.[15] Of course, for some borrowers, the time between when mortgage rates hit their trigger rates and when they actually refinance might be long because these borrowers rarely pay any attention to refinancing opportunities. They may not notice changes in interest rates unless there is an external prompt, such as a major news story or a suggestion from a friend or a mortgage broker. This could lead to these borrowers refinancing well after mortgage rates first passed the borrowers' trigger rates. When a borrower refinances after her first chance to refinance at a particular rate, we refer to this as an *error of omission*.

[14] Note that the trigger rate may take into account the borrower's delays in refinancing.

[15] Related to this rational inattention is the desire to avoid any extra transaction costs that may occur if a borrower rushes to refinance (such as the need to restructure her schedule). This desire may lead to a short delay in refinancing.

We want to estimate whether borrowers make errors of omission – that is, whether they miss opportunities to refinance at their trigger rates – and, if they do, how costly the delay is. Unfortunately, we do not observe a borrower's trigger rate. However, we can use the rate at which the borrower eventually refinances as a proxy for the trigger rate. For most borrowers in relatively stable interest rate environments, the eventual refi rate (ERR) is close to the trigger rate, although it often is somewhat below it. The less carefully that a borrower monitors mortgage rates (and their own credit ratings), the more the ERR will be below the borrower's trigger rate, on average.[16] We measure the cost of inattention – which we refer to as *Months inattention* (MI) – as the number of months prior to a refinancing that the average mortgage rate is below the average mortgage rate in the month of the refi. The reason we compare average mortgage rates is that we want to compare similar rates and we do not observe the mortgage rates that a specific borrower could receive in months that she does not refinance. Our measure of inattention gives the number of months that a borrower, had she been paying attention, could have refinanced at a rate no higher than her ERR. To illustrate our measure of inattention, we show in Figure 2 the average market mortgage rates from July 2006 through September 2008. Assume that a borrower took her initial mortgage in July 2006 and then refinanced in July 2008. The average mortgage rate in July 2006 was 6.76%, and it fell to 6.40% in July 2008. As shown in Figure 2, mortgage rates fell below 6.40% in October 2006 and remained below 6.40% through May 2007. After rising to 6.70%, rates then fell below 6.40% again in September 2007 and stayed below 6.40% until July 2008, when our hypothetical borrower refinanced. Thus, for 18 of the 24 months the mortgage was outstanding, the average mortgage rate was below the

[16] Paying less attention means having a longer expected time until the next observation of the mortgage rate. Viewing refinancing is an option means that having a longer time between observations is like having a European option with a longer maturity. In the same way that the option is more valuable when it has a longer maturity, a refi is, on average, at a lower interest rate relative to the trigger rate (the "strike price") when there is a longer time period between observations of the mortgage rate.

average mortgage rate of the month in which the borrower eventually refinanced. So, for this mortgage, the *Months inattention* measure is 18 months.

Most borrowers refinance relatively quickly once mortgage rates reach their trigger rates. On average, mortgage rates are only below the ERR for 2.66 months before refinancing (see Table 1). This is not inconsistent with relatively attentive borrowers using a rule of thumb. A rationally inattentive borrower may not notice a change in mortgage rates right away, or she might be too busy to refinance immediately. A very inattentive borrower is likely to take more than a few months before getting around to refinancing.[17] Only 17.0% of borrowers refinance when the mortgage rate has been below their ERR for at least six months. This is consistent with many – but not all – borrowers having a rule for refinancing and moving somewhat quickly when mortgages rates hit their trigger rates. Borrowers that refinance at or near the optimal refi rate seem less inattentive, on average, which is consistent with these borrowers being more financially sophisticated both in their choice of a refi rate and in their awareness of mortgage rates.

To examine how borrowers refinancing decisions are made, we next analyze the data to see if certain borrower, mortgage, and market characteristics are associated with suboptimal repayment – measured either by refinancing at the wrong mortgage rate or at the wrong time – more likely. While we control for other factors, we focus on those related to financial sophistication, the potential for inattention, and the incentives to refinance.

Our primary proxies for financial sophistication are the borrower's FICO credit score and income at the time the mortgage is refinanced. The FICO credit score is a measure of the quality of the mortgage, and is based largely on the borrower's financial condition. The mean FICO

[17] There is also the possibility that the value of refinancing at a given rate increases over time because of shifts in other factors such as expected future mortgage rates.

score is 740 (Table 1).[18] We expect that a higher FICO is associated with a more sophisticated borrower.[19] The chart on the left-hand side of Panel A of Figure 3 shows the average FICO score as a function of the *signed refi error*. The figure indicates that average FICO scores are highest when borrowers refinance at a rate slightly above the optimal refi rate. Borrowers that refinance at rates well above or below the optimal rate have lower FICO scores on average. The chart on the right-hand side of Panel A of Figure 3 shows the average FICO score as a function of *Months inattention*. Interestingly, the pattern appears bimodal. High-FICO-score borrowers are more likely to refinance at close to the optimal time or at a four- to six-month delay. This suggests that some high-FICO-score borrowers follow rates closely and refinance on time, while others may be distracted.

The mean income of borrowers in our sample is $77,495 (measured at the time of the refi). Since the distribution of income is skewed, we use the log of income in our analysis.[20] The chart on the left-hand side of Panel B of Figure 3 illustrates the average of *log(income)* as a function of the *signed refi error*. Average income is higher for borrowers that refinance at a larger signed refi error. This suggests that the average income is increasing in *Δrate* – something that is true for borrowers that refinance at a rate that is lower than their initial mortgage rate (not shown). There is no strong relationship between *log(income)* and *Months inattention* (right-hand side of Panel B of Figure 3).

The decision on what rate and when to refinance a mortgage may also depend on how important the mortgage is to the borrower. If the mortgage payments are large relative to the

[18] It is important to note that by restricting our sample to 30-year prime fixed-rate mortgages, we are missing the subprime and “Alt-A” mortgage markets. This means the average FICO score in our sample is higher than that for the average mortgage borrower.

[19] Amromin et al. (2011) document that FICO scores and incomes are correlated with financial sophistication. Specifically, they find that consumers with higher FICO scores and income were less likely to take out complex mortgages.

[20] We winsorize log(income) and the ratios including income at the 1% level to further minimize the impact of extremely high income borrowers.

borrower's income, then the ability to reduce the payments may lead the borrower to pay more attention to mortgage rates and to refinance more quickly. We measure the importance of the mortgage to the borrower by using the ratio of the mortgage size to the borrower's income. The charts in Panel C of Figure 3 show the relationship between the mortgage-to-income ratio and the *signed refi error* and the *Months inattention*. The average mortgage-to-income ratio is increasing in the *signed refi error*. This is consistent with borrowers refinancing at a smaller rate differential when a mortgage is more important to them. Interestingly, there is no relationship between this ratio and *Months inattention*, perhaps because *Months inattention* is based on the eventual refi rate and not the trigger rate.

Our analysis so far suggests that a fair number of borrowers refinance at suboptimal mortgage rates and that the decisions about refinancing are related to the level of the borrower's financial sophistication and to the importance of the mortgage to the borrower. We hypothesize that *Months inattention* decreases as the financial sophistication of the borrower increases and that it declines as the importance of the mortgage to the borrower rises. To test this, we use:

Months inattention = f(*FICO, log(income), log(mortgage/income),* other controls). (1)

If we are correct, *Months inattention* is decreasing as *FICO*, *log(income)*, and *log(mortgage/ income)* are increasing.

We expect that less financially sophisticated borrowers also have trigger rates that are further from optimal. That said, because we only observe the ERR and not the trigger rate, we want to account for the difference between observed refi error and the potential error in the trigger rate made by the borrower. To do this, we use the relationship between *Months inattention* and the average error between the trigger rate and the ERR. However, because *Months inattention* can be related to financial sophistication, we only want to use the information in the *Months* *inattention* variable that does not reflect sophistication. So, we take the residual from (1) – *MI residual* - and include it as a control. This gives us a baseline specification of:

r*efi error* = f(*FICO*, *log(income)*, *log(mortgage/income)*, *MI residual*, other controls). (2)

We run the system (1) and (2) using three-stage least squares (3SLS). The 3SLS combines two-stage least squares (2SLS) and seemingly unrelated regressions (SUR). SUR incorporates the serial correlation among the errors in different equations. In our case, there are two equations: *Months inattention* and *refi error*. 2SLS, also called the instrumental variables (IV) procedure, uses the predicted value of the endogenous variables based on IVs in the second stage. In our case, *Months inattention* is specified as one of the explanatory variables in the *refi error* equation, but is correlated with errors. The 3SLS generalizes the 2SLS to take account of the correlation between equations in the same way as SUR. It is implemented in three steps: predict *Months inattention* using IVs; use 2SLS to get the residuals to estimate the cross-equation correlation matrix; and determine the final 3SLS that incorporates the correlation matrix.

In the baseline regressions, we have a limited set of additional controls. Year of loan origination, year of refinance, and state dummies are in the regression to control for cohort and other macro events and trends.

4.1 Regressions Results

The regressions focus on the impact of two factors – the borrowers' financial sophistication and the importance of the mortgage to the borrowers. The results in the first column of Table 2 give the key coefficients from the regression results.

There is evidence that errors of omission (errors resulting from waiting too long to refinance) are more common for less sophisticated borrowers. The number of months that the mortgage rate is below the ERR is decreasing as the FICO score and log income are increasing (see the coefficients in the first column of Table 2). Moving from a 800 FICO score to a 700 FICO score, all else being equal, indicates an increase of 0.34 months in waiting time (–3.418 * (0.800 – 0.700) = –0.34), or about 13% of the sample's average *Months inattention.* The coefficient on *log(income*) is also negative and significant, consistent with sophisticated borrowers making smaller errors of omission. A decrease in *log(income)* of 0.5, about one standard deviation, implies that a borrower spends 0.14 months of additional time with the mortgage rate below the ERR, or 5% of the sample's average *Months inattention*.

The results also show that borrowers appear to be less attentive when their mortgages are less important to them. The coefficient on the log of the mortgage-to-income ratio is negative and significant in the regression in the first column of Table 2. Increasing the mortgage-to-income ratio by one standard deviation from its mean leads to an extra 0.09 months of inattention, or about half the magnitude as a one standard deviation change in the FICO score.

We next turn to examining errors of commission – that is, refinancing at a suboptimal mortgage rate differential. As with errors of omission, borrowers make smaller errors of commission when they are more sophisticated and when mortgages are more important to them. Using the results given in the second column of Table 2, the expected refi error for a borrower with an 800 FICO score is 1.73 basis points lower than the expected refi error for a borrower with a 700 FICO score. This drop is 3% of the average refi error. Similarly, a one standard deviation increase in *log(income)* is associated with a 9% decrease in the average refi error. Increasing *log(mortgage/income)* – our measure of the importance of a mortgage to a borrower – by one standard deviation leads us to a prediction of an 8% decrease in the average refi error.

Inattentive borrowers, all else being equal, make larger refinancing mistakes. *MI residual* is the residual from the *Months inattention* regression (1). As explained earlier, it measures the inattention not explained by our measures of financial sophistication and mortgage importance to a borrower. The positive and significant coefficient on *MI residual* in the second column of Table 2 indicates that borrowers who are more inattentive make larger refinancing errors.

4.2 Repeat Refinancing

Borrowers can learn from refinancing. The decision about when refinancing is correct is complicated (ADL, 2012) and may be unlike other financial decisions borrowers have made. This can be intimidating. Of course, experience can help borrowers make better decisions. In this section, we explore whether borrowers learn from refinancing.

Our sample contains 4,882 mortgages where we know that the borrower refinanced for a second time. The borrowers that refinance twice appear more sophisticated than those that refinance only once. At the time of the first refi, refinancers who have refinanced twice have higher FICO scores (higher by 16) and larger incomes (13% larger) than other refinancers. Such differences may explain why second-time refinancers have slightly smaller refi errors (53 basis points versus 60 basis points) and fewer *Months inattention* (2.3 months versus 2.7 months).

To see whether borrowers learn from refinancing, we introduce a dummy variable that takes the value one if and only if a refinancing is the second one by that borrower. We then repeat the baseline regression with the second refi dummy added. The results are reported in the first two columns of Table 3. The coefficients on the second refi dummy are negative and significant for both the *Months inattention* and refi error stages. This suggests that borrowers learn something from their first refinancing that allows them to make smaller errors the second time. The other coefficients in the regression are similar to those in the baseline regression.

We also run the baseline regression with the second refi dummy added for just the sample of borrowers with two refis. Using the full sample makes the assumption that borrowers with multiple refinancings are like other borrowers – something that may not be true. The results for the sample of borrowers with second refis (but no interaction term) are reported in the final two columns of Table 3. The results are qualitatively similar to the full sample results, although the fit is weaker. However, the second refi dummy is negative and significant in both stages, again implying that borrowers learn something from their first refinancing that allows them to make smaller errors the second time.

4.3. Robustness

The results in sections 4.1 and 4.2 indicate that refinancing decisions may depend on the financial sophistication of borrowers and the incentives of borrowers to pay careful attention to mortgage rates. In this section, we examine additional factors that may affect the decision to refinance.

The cost of an error of omission is related to the potential benefits forgone. That is why we measure *Months inattention* as the number of months the average mortgage rate is below the average mortgage rate at the time of the refinancing rather than as the number of months since the first time the average mortgage rate is below the average mortgage rate at the time of refinancing. But our baseline measure of inattention does not factor in the *degree* to which the average mortgage rate falls below the average mortgage rate at the time of refinancing; it only accounts for the period of inattention. To see whether this matters, we use an alternative measure of the cost of inattention. Let *cumulative loss* on a refi be

$$\sum_{m=1}^{r}\{MR_r - MR_m | MR_r > MR_m\},$$

where MR_t is the average mortgage rate in month t, month 1 is the origination month for the initial mortgage, and month r is the month in which the mortgage is refinanced. So, *cumulative loss* measures the area below the dashed line and above the solid line in Figure 2. Using this measure, failing to refi in a month where the mortgage rate is 100 basis points below the market rate when the mortgage is refinanced is twice as bad a failing to refi in a month where the mortgage rate is 50 basis points below the market rate when the mortgage is refinanced. Comparing the results presented in Table 4 to those in Table 2 shows that using *cumulative loss* rather than *Months inattention* does not change the qualitative conclusions of our analysis.

Our baseline model uses a parsimonious set of independent variables intended to control for financial sophistication and the importance of a mortgage to a borrower. We now include additional independent variables to explore whether refinancing behavior is affected by expectations, local market conditions, and behavioral factors.

The optimal refi rate for a borrower depends on that borrower's particular circumstances. One factor that plays a role in the optimal refinancing rate is the path of future interest rates. If rates are expected to fall, borrowers have an incentive to have a lower trigger rate. We examine whether borrowers are forward looking in this respect by adding a measure of future interest rates to our regressions. The steepness of the yield curve provides a signal of the path of interest rates in the future. Often, researchers use the difference between a long-term Treasury bond rate and a short-term Treasury bill rate as a measure of where short-term interest rates are headed. But we care about the interest rate on a 30-year FRM, which is priced off of long-term interest rates, so we define the *long-yield curve* as the difference between the ten-year Treasury bond rate and the five-year Treasury bond rate (we use the constant maturity yields for both of these). A steeper long-yield curve, that is a larger value of the *long-yield curve*, indicates that, all else being equal, mortgage rates should rise more in the future. Borrowers that expect mortgage rates to increase have an incentive to refinance quickly.

Borrowers who are more financially sophisticated should be better at realizing that the yield curve slope is an indicator of the incentives to refinance. To test this, we interact our primary measure of financial sophistication, the FICO score, with our yield curve measure using the variable *FICO * long-yield curve*.

A borrower may miss refinancing opportunities when mortgage rates first hit her trigger rate because she is not constantly monitoring rates. The incentives to monitor mortgage rates depend on other matters vying for the borrower's attention but also on the probability that a search on mortgage rates yields a rate below the trigger rate. The value of searching is a function not just of the average mortgage rate nationwide, but also of local market conditions. We introduce local market conditions by adding two variables. The first is the average mortgage rate in the borrower's home state in the same year as the refi. The second is the standard deviation of the mortgage rates for all mortgages in our sample that are made in the borrower's home state in the refi year. Low rates might encourage searching. The disparity of mortgage rates at different lenders in a market may affect refinancing decisions. To measure this, we use the standard deviation of rates on 30-year FRMs in a local market in a particular month. The impact of a higher standard deviation may depend on whether the borrower is aware of the dispersion in local rates before she searches for a refinancing. If she is aware, then a larger standard deviation should lead to more searches. However, if the borrower is not aware, then a larger standard deviation should not affect the number of searches; rather, the borrower should take longer to find a mortgage with an attractive interest rate, but the rate, on average, should be lower.

There is also the possibility the borrowers may make decisions looking backward, consistent with evidence that psychological factors such as regret play a role in financial decisions (Michenaud and Solnik, 2008). For example, if mortgage rates are rising, borrowers might be more likely to refinance because they know they would regret it if they missed out on an opportunity to profitably refinance. To capture this, we examine how refinancing decisions are affected by sharp increases in mortgage rates. Let *up move* be a dummy variable that takes the value one if and only if the average mortgage rate in the economy in a month is at least 50 basis points more than it was at its minimum in the prior six months. On average, 14% of refis take place when *up move* = 1 (see Table 1).

In addition, let *down move* be a dummy variable that takes the value one if and only if the average mortgage rate in the economy in a month is at least 50 basis points less than it was at its maximum in the prior six months. As with *up move*, past interest rates should not affect mortgage decisions. Of course, if people assume that economic trends affecting mortgage rates will continue, then they might hold off on refinancing when rates are falling. The general downward trend of mortgage rates during the sample period results in 55% of refis taking place when *down move* = 1 (Table 1).

One issue with both the *up move* and *down move* dummies is that they are somewhat mechanically correlated with *Months inattention*. If mortgage rates are increasing in the months prior to a refi, then the expected time the rate is below the eventual refi rate is longer. This induces a positive correlation. Similarly, there should be a negative correlation between *down move* and *Months inattention*. However, the relationship between the two dummies and the refi error should reflect behavioral issues.

Table 5 presents the results of regressions with the new variables added to the baseline specification. The coefficients on the baseline control variables in Table 5 are qualitatively similar to those in the baseline model presented in Table 2.

When the yield curve is steeper, indicating that rates may increase in the future, borrowers refinance more quickly and make smaller errors. To see this, we have to combine the effects of the coefficients on the *long-yield curve* variable and the *long yield-FICO* interaction term. At the mean FICO score (740), an increase of 100 basis points in the long-yield curve slope reduces *Months inattention* by 2.1 months (–2.097 + 0.74 * 0.052) and reduces the refi error by 19 basis point (–19.477 + 0.74 * 0.861).

As the long-yield curve gets steeper, the impact of financial sophistication on *Months inattention* is reduced as shown by the positive coefficients on *FICO * long-yield curve slope* in the first three regressions of Table 5. An increase of 60 basis point in the FICO score reduces *Months inattention* by 0.38 months when the long-yield curve slope is 0.5. When the slope is 0.83 (its mean value), an increase of the FICO score by 60 points only reduces *Months inattention* by 0.18 months. This is consistent with otherwise inattentive borrowers paying more attention when there is more to gain.

The regression coefficients reported in Table 5 are consistent with fewer searches when local market rates are higher than the national average. The coefficients on the mean mortgage rate in the local market are positive and significant. Borrowers wait longer to refinance and, perhaps because of that, make larger refinancing rate errors. The coefficient on the standard deviation variables in the inattention regression is positive. This may indicate that borrowers have an idea of what the average mortgage rate in a market is and continue to search when they get a rate above that rate. If a market has a higher dispersion of rates, then it is more likely that a borrower gets a high rate when she searches. We find no statistically significant relationship between the standard deviation of local market rates and refinancing rate errors.

There is also evidence that behavioral factors affect errors of commission. The coefficient on *up move* is positive and significant. This would occur if borrowers feared missing out if rates continued to increase. The negative coefficient on *down move* suggests that in a falling-rate environment, borrowers are more likely to patiently wait for a closer-to-optimal refinancing opportunity. The impact of these factors is economically significant as well; with a 9 BP (15% of the mean refi error) and a 15 basis point (25%) difference in the error rate when there is an up move and a down move, respectively.

While inattention likely explains why many borrowers do not refinance quickly once the mortgage rates hits their ERR, some borrowers may be unable to qualify for a new loan when mortgage rates first hit their ERR. We divide the sample by whether the loan-to-value ratio (LTV) of the refi is above or below 80%.[21] High-LTV borrowers have a very high LTV. The mean and median LTV are both around 90%. In addition, high-LTV borrowers have lower FICO scores than low-LTV borrowers. These highly levered borrowers may find it difficult (or time consuming) to qualify for a refi that reduces their monthly payments. This may explain why it takes them longer to refinance. To exclude borrowers that appear to be very inattentive or financially constrained, we drop from the sample all borrowers with an LTV for the refinanced loan of over 80%. This reduces the sample from 271,216 loans to 188,931 loans.

The first two columns of Table 6 report the results of the regressions on the low-LTV sample. The results are broadly consistent with those for the full sample. The coefficients are of the same sign and significance, and close in value, as in the baseline results. These results

[21] Since we drop refis where the borrower cashes out equity, the LTV of the original mortgage at the time of the refi is close to the LTV of the refi.

suggest that what we find is not a proxy for the inability of borrowers to qualify for a refinancing.

Our sample period includes the recent financial crisis. During the crisis, home prices fell sharply and private mortgage securitization markets shutdown. These factors affected the ability of borrowers to refinance mortgages. To ensure that crisis effects are not driving our results, we run our baseline specification for the period 1998–2006. The results are given in the final two columns of Table 6. The results are qualitatively similar to the full sample results.

One key assumption of the structure of our baseline model is that the same factors influencing the error of refinancing above the optimal rates are influencing the error of refinancing below the optimal rate. As the data in Table 1 show, a substantially larger share of refis are at a rate well above the optimal rate than well below the optimal rate. We split the sample into those borrowers who refinance at a rate differential at least 50 basis points below their optimal rate (borrowers with an "itchy finger," which we henceforth refer to as IF borrowers), borrowers who refinance at a rate at least 50 basis points below the optimum (these have been referred to as "woodheads," so we refer to them henceforth as WH borrowers), and those that refinance in the optimal range (OR borrowers). Roughly 50% of the observations are in the optimal range.[22] Of those that are not, IF borrowers outnumber WH borrowers by a ratio of five to one.

To see whether the three groups of borrowers are affected similarly by their level of financial sophistication and the importance of their mortgages to them, we run our baseline regression separately for each of the three groups. The results are reported in Table 7.

[22] This figure is slightly different from the percentage in the introduction because some observations in our raw data are not in the regressions because of missing observations for the independent variables.

Errors of omission are decreasing with an increase in the level of financial sophistication for all three groups of borrowers. The coefficients on the *FICO* variable in the *Months inattention* stage are negative and significant for IF, OR, and WH borrowers. In addition, the coefficient on the *log(income)* variable is negative and significant for IF borrowers.

The IF borrowers make fewer errors of omission when a mortgage is more important to them as the *log(mortgage/income)* variable is negative and significant in the *Months inattention* stage of the regression. There is no significant impact of mortgage importance for the other groups of borrowers.

In all three groups, errors of commission are smaller for borrowers who are more sophisticated and when a mortgage is more important. In the *refi error* stage of the regression, the coefficients on *FICO*, *log(income)*, and *log(income/mortgage)* are negative and significant for IF, OR, and WH borrowers.

In the baseline results, refi errors are increasing in borrower distraction as measured by the *MI residual*. The split sample results suggest this is largely due to the WH borrowers. This is evidence that WH borrowers may make large mistakes because they do not pay attention to mortgage rates, thus missing out optimal refinancing opportunities when rates first hit their trigger rates.

Overall, the split sample results suggest that financial sophistication is correlated with refinancing decisions not only in the full sample but also for various different types of borrowers (high-LTV, IF, and WH borrowers).

5. Conclusions

Choosing when to refinance a mortgage is one of the most important decisions people face. The standard option-pricing approach to refinancing when there are transaction costs implies there is an optimal interest-rate differential above which borrowers should refinance. It has long been recognized that borrower behavior does not match the predictions of the model. We find evidence consistent with this: Borrowers in our sample refinance at mortgage rates that are, on average, 60 basis points higher than the optimal rate for those borrowers, with 52% of borrowers missing by at least 50 basis points. We call such misses errors of commission. Most often, borrowers miss by refinancing at too small an interest rate differential.

To refinance optimally, a borrower must not only choose the correct interest rate differential, but she must also refinance at the correct time. We examine errors of omission, which involve waiting too long to refinance. We find that mortgage rates are below the rate when a borrower eventually refinances for an average of 2.7 months during the life of a mortgage, but 17% of borrowers wait at least six months too long.

We examine how errors of commission and omission are related to borrower characteristics. We find that borrowers who are likely to be more financially sophisticated (as proxied by larger FICO scores or higher income) make smaller errors of both kinds. Also, we provide evidence that borrowers make fewer errors when a mortgage is more important to them (as proxied by a higher ratio of the mortgage size to the borrower's income).

Borrowers appear to learn from the refinancing process. Refinancing errors, both of commission and omission, are smaller when a borrower refinances for the second time. There is some evidence that this might be related to the level of a borrower's financial sophistication.

Some refinancing errors are likely due to the borrower being distracted with other matters. Borrowers that make larger errors of omission for reasons unrelated to financial sophistication or mortgage importance – errors we interpret as being due to distraction – also make larger errors of commission. Overall, we find that borrower characteristics can go a long way toward explaining the errors of commission and omission in mortgage refinancing decisions. Our results have policy implication as outlined in Campbell, Jackson, Madrian, and Tufano (2011).

References

Agarwal, Sumit, Itzhak Ben-David, and Vincent Yao, 2012, “Systematic Mistakes of Borrowers in the Mortgage Markets” Working Paper, Ohio State University.

Agarwal, Sumit, Souphala Chomsisengphet, Chunlin Liu, and Nicholas Souleles, 2007, “Do Consumers Optimally Choose Credit Contracts?” Working Paper, University of Pennsylvania.

Agarwal, Sumit, John C. Driscoll and David I. Laibson, 2012, "Optimal Mortgage Refinancing: A Closed Form Solution" *Journal of Money, Credit, and Banking*, forthcoming.

Agarwal, Sumit, and Bhashkar Mazumder, 2013, “Cognitive Ability and Financial Decision Making” forthcoming, *American Economic Journal: Applied Economics*

Agarwal, Sumit, Paige Skiba, and Jeremy Tobacman, 2009, “Payday Loans and Credit Cards: New Liquidity and Credit Scoring Puzzles?” *American Economic Review: Papers and Proceeding*, 99 (2), 412-417.

Amromin, Gene, Jennifer Huang, Clemens Sialm, and Edward Zhong, 2011, “Complex Mortgages” Federal Reserve Bank of Chicago Working Paper

Archer, Wayne and David Ling, 1993, “Pricing Mortgage-Backed Securities: Integrating Optimal Call and Empirical Models of Prepayment,” *Journal of the American Real Estate and Urban Economics Association*, 21(4), 373-404.

Ball, L., G. Mankiw, and R. Reis, 2003, “Monetary Policy for Inattentive Economies,” *Journal of Monetary Economics*, NBER Working Paper

Barber, B., and T. Odean, 2008, “All that Glitters: The Effect of Attention and News on the Buying Behavior of Individual and Institutional Investors” *Review of Financial Studies*, 21, 785-818.

Ben-David, Itzhak, 2011, Financial Constraints and Inflated Home Prices during the Real-Estate Boom, *American Economic Journal: Applied Economics* 102(3), 559-578.

Bennett, Paul, Richard Peach, and Stavros Peristiani, 2000, “Implied Mortgage Refinancing Thresholds,” *Real Estate Economics*, 28(3), 405-434.

Bennett, Paul, Richard Peach, and Stavros Peristiani, 2001, “Structural Change in the Mortgage Market and the Propensity to Refinance,” *Journal of Money, Credit and Banking*, 33(4), 955-975.

Calvo, Guillermo, 1983, “Staggered Prices in a Utility-Maximizing Framework.” *Journal of Monetary Economics*, 23(3), 383-398.

Campbell, John, 2006, "Household Finance." *Journal of Finance*, 56(4), 1553-1604.

Campbell, John, Howell Jackson, Brigitte Madrian, and Peter Tufano, 2011, "Consumer Financial Protection," 2011, *Journal of Economic Perspectives* 25(1): 91-114

Chang, Yan and Abdullah Yavas, 2009, "Do Borrowers Make Rational Choices on Points and Refinancing?" *Real Estate Economics,* 37(4), 638-658.

Choi, James, Brigitte Madrian, and David Laibson, 2012, “$100 Bills on the Sidewalk: Violations of No-Arbitrage in 401(k) Accounts,” *The Review of Economics and Statistics*, 113(3):748-63.

Chen, Andrew and David Ling, 1989, "Optimal Mortgage Refinancing with Stochastic Interest Rates," *AREUEA Journal*, 17(3), 278-299.

Cole, Shawn and Gauri K. Shastry, 2009. “Smart Money: The Effect of Education, Cognitive Ability, and Financial Literacy on Financial Market Participation,” Harvard Business School, Working Paper.

Deng, Yongheng, and John Quigley, 2006, “Woodhead Behavior and the Pricing of Residential Mortgages," Working Paper, University of California-Berkeley.

Della Vigna, S., and J Pollet, 2009, “Investor Inattention and Friday Earnings Announcements,” *Journal of Finance*, 64, 709-749.

Dickinson, Amy and Andrea Hueson, 1994, "Mortgage Prepayments: Past and Present," *Journal of Real Estate Literature,* 2(1), 11-33.

Downing, Christopher, Richard Stanton and Nancy Wallace, 2005, "An Empirical Test of a Two-Factor Mortgage Valuation Model: How Much Do House Prices Matter?" *Real Estate Economics*, 33(4), 681-710.

Dunn, Kenneth B. and John McConnell, 1981a, "A Comparison of Alternative Models of Pricing GNMA Mortgage-Backed Securities." *Journal of Finance*, 36(2), 375-92.

Dunn, Kenneth B, and John McConnell, 1981b, "Valuation of GNMA Mortgage-Backed Securities." *Journal of Finance*, 36(3), 599-617.

Dunn, Kenneth B. and Chester S. Spatt, 2005, "The Effect of Refinancing Costs and Market Imperfections on the Optimal Call Strategy and the Pricing of Debt Contracts." *Real Estate Economics*, 33(4), 595-617.

Fannie Mae, 2012, Fannie Mae National Housing Survey, q1 2012 Data Summary, http://www. fanniemae.com/resources/file/research/housingsurvey/pdf/datasummary-q12012nhs. pdf, page 88, accessed on October 26, 2012.

Follain, James R., Louis O. Scott and T.L. Tyler Yang, 1992, "Microfoundations of a Mortgage Prepayment Function." *Journal of Real Estate Finance and Economics*, 5(1), 197-217.

Gabaix, Xavier and David I. Laibson, 2001, "The 6D Bias and the Equity- Premium Puzzle." NBER Macroeconomics Annual.

Giliberto, S. M., and T. G. Thibodeau, 1989, "Modeling Conventional Residential Mortgage Refinancing." *Journal of Real Estate Finance and Economics*, 2(1), 285-299.

Green, Jerry, and John B. Shoven, 1986, "The Effects of Interest Rates on Mortgage Prepayment," *Journal of Money, Credit, and Banking*, 18(1), 41-59.

Greenspan, Alan, and James Kennedy, 2008, Sources and Uses of Equity Extracted from Homes, *Oxford Review of Economic Policy* 24, 120-144.

Harding, J. P., 1997, "Estimating Borrower Mobility from Observed Prepayment." *Real Estate Economics*, 25(3), 347-371.

Hendershott, Patrick and Robert Van Order, 1987, "Pricing Mortgages--An Interpretation of the Models and Results." *Journal of Financial Services Research*, 1(1), 19-55.

Hilgert, Marianne A., Jeanne M. Hogarth, and Sandra G. Beverly, 2003. "Household Financial Management: The Connection between Knowledge and Behavior," *Federal Reserve Bulletin*, 89(7), 309-322.

Hurst, Erik, 1999, "Household Consumption and Household Type: What Can We Learn from Mortgage Refinancing?" Mimeo, University of Chicago.

Hurst, Erik, and Frank Stafford, 2004, "Home is Where the Equity is: Mortgage Refinancing and Household Consumption." *Journal of Money, Credit, and Banking*, 36(6), 985-1014.

Jiang, Wei, Ashley Nelson and Edward Vylacil, 2012, "Liar's Loan? – Effects of Origination channel and Information Falsification on Mortgage Loan Delinquency," *Review of Economics and Statistics*, forthcoming.

Kau, James and Donald Keenan, 1995, "An Overview of the Option-Theoretic Pricing of Mortgages." *Journal of Housing Research*, 6(2), 217-244.

Keys, Benjamin J., Tanmoy K. Mukherjee, Amit Seru, and Vikrant Vig, 2010, Did Securitization Lead to Lax Screening? Evidence from Subprime Loans, *Quarterly Journal of Economics* 125(1), 307-62.

Korniotis, George and Alok Kumar, 2011, "Do Older Investors Make Better Investment Decisions?" *Review of Economics and Statistics*, 93(1), 244-265.

LaCour-Little, Michael, 1999, "Another Look at the Role of Borrower Characteristics in Predicting Mortgage Prepayments." *Journal of Housing Research*, 10(1), 45-60.

Li, Geng, 2012. "Information Sharing and Stock Market Participation: Evidence from Extended

Families," *Review of Economics and Statistics*, forthcoming.

Longstaff, Francis A. "Optimal Recursive Refinancing and the Valuation of Mortgage-Backed Securities." NBER Working Paper 10422.

Mankiw, N. Gregory and Ricardo Reis, 2002, "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve." *Quarterly Journal of Economics*, 117(4).

Michenaud, Sebastien, and Bruno Solnik, 2008, "Applying regret theory to investment choices: Currency hedging decisions," Working Paper.

Reis, Ricardo, 2006, "Inattentive Producers," *Review of Economic Studies*, 73(3), 793-821.

Richard, Scott F. and Richard Roll, 1989, "Prepayments on Fixed-Rate Mortgage-Backed Securities." *Journal of Portfolio Management*, Spring, 73-82.

Schwartz, Eduardo S., and Walter N. Torous, 1989, "Prepayment and the Valuation of Mortgage Pass-Through Securities." *Journal of Finance* , 44(2), 375-392.

Schwartz, Eduardo S., and Walter N. Torous, 1992, "Prepayment, Default, and the Valuation of Mortgage Pass-Through Securities." *Journal of Business*, 65(2), 221-239.

Schwartz, Eduardo S., and Walter N. Torous, 1993, "Mortgage Prepayment and Default Decision: A Poisson Regression Approach," *Journal of the American Real Estate and Urban Economics Association*, 21(4), 431-449.

Sims, Christopher A., 2003, "Implications of Rational Inattention," *Journal of Monetary Economics*, 50(3), 665–690.

Stanton, Richard, 1995, "Rational Prepayment and the Valuation of Mortgage-Backed Securities." *Review of Financial Studies*, 8(3), 677-708.

Yang, T.L. Tyler, and Brian A. Maris, 1993, "Mortgage Refinancing with Asymmetric Information." *Journal of the American Real Estate and Urban Economics Association*, 21(4), 481-510.

Appendix: Optimal refinancing rate

In deciding whether to refinance, a borrower must trade off the gains from refinancing against the costs of doing so. The borrower incurs the cost of refinancing (direct and indirect cost), which is why the optimal rate at which a borrower should refinance is strictly less than the rate on the borrower's existing mortgage. Determining when the option to refinance is "in the money" is a complicated function of factors, including the remaining maturity of the initial mortgage and the expected path of future interest rates. We follow Agarwal, Driscoll, and Laibson (2012; henceforth, ADL) to estimate the optimal refinance rate or, equivalently, the optimal refi rate differential. In ADL, refinancing is optimal when the difference between the mortgage rate at refinancing and the mortgage rate at the time the mortgage was issued is less than or equal to Δr^*, where Δr^* is defined as

$$\Delta r^* \equiv \frac{1}{\psi}\left[\varphi + W\left(-exp(-\varphi)\right)\right]. \quad \text{(X1)}$$

In (X1), $W(.)$ is the Lambert W-function and the values of ψ and ϕ are given by

$$\psi = \frac{\sqrt{2(\rho+\lambda)}}{\sigma}, \quad \text{(X2)}$$

$$\phi = 1 + \psi(\rho+\lambda)\frac{\kappa/M}{(1-\tau)}, \quad \text{(X3)}$$

where ψ is a function of the expected real repayment rate λ, the real discount rate ρ, and the annualized standard deviation of the mortgage interest rate σ; and where ϕ is a function of the remaining mortgage balance M, the transaction cost of refinancing κ, and the marginal tax rate τ (which is a function of income in the year in which the mortgage was refinanced). The expected real repayment rate λ is defined in equation (X4),

$$\lambda = \mu + \frac{i_0}{\exp[i_0\Gamma]-1} + \pi \quad \text{(X4)}$$

where λ is a function of the original mortgage interest rate i_0, the probability of moving per year μ, the remaining mortgage term Γ, and the inflation rate π (measured as the percentage change in Consumer Price Index from the previous year). To estimate (X1), we use our data for most of the variables, but follow ADL in setting the discount rate (5%), the standard deviation of mortgage interest rates (0.0109), the cost of refinancing ($0.01M$ + $2,000), and the probability of moving (10%).

The optimal refinancing rate differential can change significantly as a function of the parameters. For a mortgage of $190,000, close to the median size in our data, the optimal refi rate differential $\Delta r^* = -1.03\%$.[23] The size of the mortgage affects the optimal refinancing rate, with borrowers typically taking out a $130,000 mortgage (the 25th percentile in our sample) having an optimal refi rate differential of –1.22% and those with a $260,000 mortgage (the 75th percentile in our sample) having an optimal refi rate differential of –0.87%. The optimal rate differential is decreasing as the mortgage size increases largely because the fixed costs of refinancing are a smaller fraction of a larger mortgage balance.

[23] The calculations in this paragraph are based on the actual incomes of borrowers in our data that take mortgages of these sizes.

Table 1. Summary statistics.

Summary statistics based on 30-year FRM that refinance 30-year FRM where both mortgages are originated between 1998 and 2010. To be in the sample, mortgages must be purchased by Fannie Mae or Freddie Mac and not be used to cash out equity. The sample contains 271,216 observations.

Variable	Mean	SD	Median
Δrate: Interest rate difference (refi rate – initial mortgage rate, in BP)	-120.98	50.76	-119.90
Optimal refi rate differential (BP)	-157.85	51.52	-159.55
Refi error (BP)	59.80	45.52	50.26
Months from origination to refinance	28.32	21.94	22.00
Months inattention	2.66	4.10	1.00
FICO	740	52	751
Borrower income at refi ($1000s)	7.57	6.60	6.50
Log(income)	8.77	0.54	8.78
Mortgage size ($1000s)	203.19	95.99	184.00
Mortgage-to-income ratio	31.45	13.33	28.88
Log(Mortgage/income)	3.36	0.41	3.36
Second refi dummy	0.02	0.13	0.00
Long-yield curve slope (pct. points)	0.99	0.31	1.04
up move dummy	0.14	0.34	0.00
down move dummy	0.55	0.50	1.00
Mean mortgage rate by state (pct. points)	5.48	0.76	5.06
Std. dev of mortgage rate by state (pct. points)	0.36	0.06	0.37
Refi year	2006	4	2009

Table 2. Baseline regression results.

Results based on 3SLS regression where the dependent variables are *Months inattention*, the months between the origination of the initial mortgage and origination of the refi when the mean mortgage rate is less than the mean mortgage rate at the time of the refinancing, and *Refi error*, the absolute value of the difference between the optimal rate at which a borrower should refinance and the actual rate at which the borrower refinances. The regression has state fixed effects, origination year fixed effects, and refi year fixed effects. Robust standard errors in parentheses.

	Dependent Variables	
	Months inattention	*Refi error*
FICO/1000	-3.418***	-16.703***
	(-23.89)	(-9.96)
Log(mortgage/income)	-0.221***	-11.939***
	(-8.90)	(-41.61)
Log(income)	-0.277***	-10.382***
	(-14.26)	(-45.98)
MI (months inattention) residual		0.235**
		(2.96)
Observations	271,216	
Adjusted R-squared	0.223	0.162

Table 3. Regression results including control for second refinancings.

Results based on 3SLS regressions where the dependent variables are *Months inattention*, the months between the origination of the initial mortgage and origination of the refi when the mean mortgage rate is less than the mean mortgage rate at the time of the refinancing, and *Refi error*, the absolute value of the difference between the optimal rate at which a borrower should refinance and the actual rate at which the borrower refinances. All regressions have state fixed effects, origination year fixed effects, and refi year fixed effects. Robust standard errors in parentheses.

	Full Sample		Borrowers with two refis only	
	Months inattention	*Refi error*	*Months inattention*	*Refi error*
FICO/1000	-3.393***	-16.045***	-3.634***	-13.482
	(-23.72)	(-9.57)	(-4.63)	(-1.41)
Log(mortgage/income)	-0.221***	-11.925***	-0.194	-17.404***
	(-8.88)	(-41.58)	(-1.44)	(-10.78)
Log(income)	-0.275***	-10.321***	-0.277**	-16.709***
	(-14.14)	(-45.73)	(-2.59)	(-12.96)
MI (months inattention) residual		0.245**		1.177*
		(3.09)		(2.55)
Second refinancing dummy	-0.380***	-9.813***	-0.285**	-15.085***
	(-7.15)	(-16.05)	(-3.13)	(-13.93)
Observations	271216		9764	
Adjusted R-squared	0.1826	0.1604	0.1619	0.1676

Table 4. Regression results using cumulative loss rather than months inattention.

Results based on 3SLS regression where the dependent variables are *Cumulative loss*, which is defined as $\sum_{m=1}^{r}\{MR_r - MR_m | MR_r > MR_m\}$, where MR_t is the average mortgage rate in month t, month 1 is the origination month for the initial mortgage, and month *r* is the month that the mortgage is refinanced, and *Refi error*, the absolute value of the difference between the optimal rate at which a borrower should refinance and the actual rate at which the borrower refinances. The regression has state fixed effects, origination year fixed effects, and refi year fixed effects. Robust standard errors in parentheses.

	Dependent Variables	
	Cumulative loss	*Refi error*
FICO/1000	-0.831***	-16.218***
	(-15.65)	(-9.73)
		0
Log(mortgage/income)	-0.101***	-11.899***
	(-10.96)	(-41.37)
Log(income)	-0.107***	-10.304***
	(-14.81)	(-45.49)
Cumulative loss residual		0.794**
		(3.09)
Second refinancing dummy	-0.104***	-9.824***
	(-5.25)	(-16.06)
Observations	271,216	
Adjusted R-squared	0.191	0.163

Table 5. Regression results with additional controls.

	Dependent variable	
	Months inattention	*Refi error*
FICO / 1000	-1.963***	-21.533***
	(-14.22)	(-9.32)
Log (income)	-0.248***	-12.597***
	(-13.08)	(-40.17)
Log (mortgage/income)	-0.257***	-10.898***
	(-17.28)	(-41.98)
MI (months inattention) residual		-1.911***
		(-4.03)
Long-yield curve slope	-2.097***	-19.477***
	(-19.14)	(-11.11)
FICO/1000 * long-yield curve slope	0.052***	0.861***
	(3.96)	(4.27)
Average mortgage rate in local market	0.873***	25.029***
	(8.86)	(16.11)
Standard deviation of mortgage rates in local market	2.848***	7.205
	(11.72)	(1.84)
up move dummy	4.795***	8.090***
	(253.03)	(3.47)
down move dummy	-3.231***	-14.076***
	(-246.84)	(-8.83)
Observations	271,216	
Adjusted R-squared	0.548	0.144

All regressions have state fixed effects, origination year fixed effects, and refi year fixed effects.
Robust standard errors in parentheses.

Table 6. Regression results with restricted samples: LTV of the borrower no larger than 80% and excluding the financial crisis.

Results based on 3SLS regression where the dependent variables are *Months inattention*, the months between the origination of the initial mortgage and origination of the refi when the mean mortgage rate is less than the mean mortgage rate at the time of the refinancing, and *Refi error*, the absolute value of the difference between the optimal rate at which a borrower should refinance and the actual rate at which the borrower refinances. The regression has state fixed effects, origination year fixed effects, and refi year fixed effects. Robust standard errors in parentheses.

	LTV ≤ 80%s		Excluding the financial crisis	
	Months inattention	*Refi error*	*Months inattention*	*Refi error*
FICO/1000	-3.498***	-17.924***	-2.600***	-16.468***
	(-19.42)	(-8.56)	(-13.52)	(-7.14)
Log(mortgage/income)	-0.375***	-13.041***	-0.417***	-12.119***
	(-12.59)	(-38.09)	(-10.62)	(-25.80)
Log(income)	-0.393***	-11.498***	-0.414***	-11.523***
	(-16.83)	(-42.56)	(-13.19)	(-30.38)
MI (months inattention) residual		0.153		-1.542***
		(1.49)		(-7.64)
Observations	188,931		121,367	
Adjusted R-squared	0.237	0.185	0.304	0.138

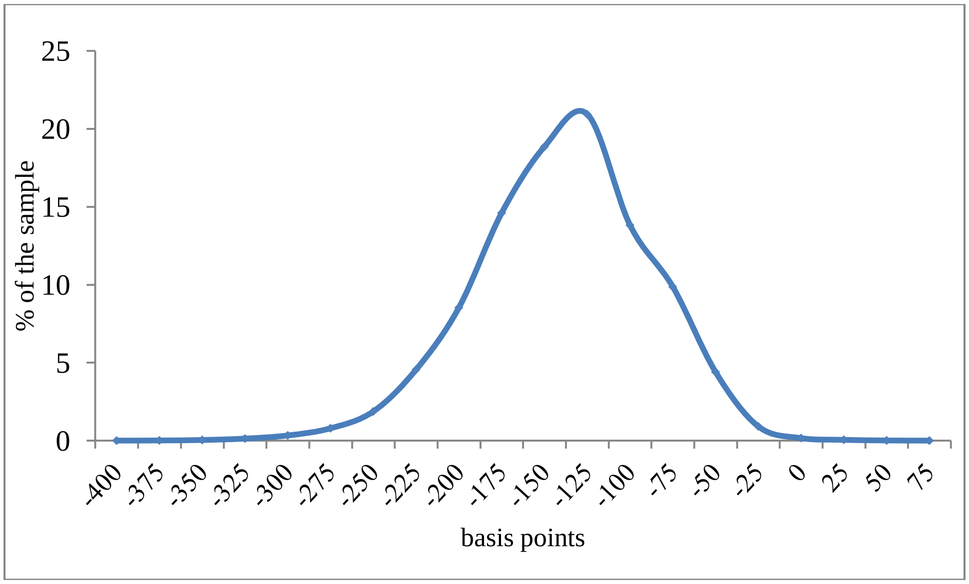
Table 7. Additional regression results.

Results based on 3SLS regression where the dependent variables are *Months inattention*, the months between the origination of the initial mortgage and origination of the refi when the mean mortgage rate is less than the mean mortgage rate at the time of the refinancing, and *Refi error*, the absolute value of the difference between the optimal rate at which a borrower should refinance and the actual rate at which the borrower refinances. The OR (optimal range) borrowers are those who refi within 50 basis points of optimal. The IP (itchy finger) borrowers are those that refi at a rate that is more the 50 basis points larger than the optimal rate and the WH (woodhead) borrowers are those that refi at a rate that is more the 50 basis points smaller than the optimal rate. The regressions have state fixed effects, origination year fixed effects, and refi year fixed effects. Robust standard errors in parentheses.

	IF subsample	OR subsample	WH subsample
Months inattention			
FICO/1000	-4.172***	-2.892***	-3.221***
	(-16.95)	(-15.98)	(-7.56)
Log(mortgage/income)	-0.295***	0.033	0.139
	(-6.90)	(1.03)	(1.81)
Log(income)	-0.379***	-0.025	0.042
	(-11.29)	(-1.02)	(0.69)
Adjusted R-squared	0.267	0.1939	0.1969
Refi error			
FICO/1000	-9.248***	-2.146**	-33.196***
	(-4.21)	(-2.60)	(-7.30)
Log(mortgage/income)	-10.287***	-0.985***	-1.978*
	(-27.53)	(-6.96)	(-2.44)
Log(income)	-8.473***	-0.811***	-2.626***
	(-28.65)	(-7.31)	(-4.08)
MI (months inattention) residual	0.081	-0.021	0.706***
	(0.75)	(-0.55)	(3.46)
Observations	113,204	134,968	23,044
Adjusted R-squared	0.137	0.011	0.028

Figure 1.

Panel A: Difference between the interest rate on a mortgage that has been refinanced and the interest rate on the initial mortgage (Δ*rate*).



Panel B: Difference between the interest rate on a mortgage that has been refinanced and the optimal interest rate at which that borrower should have refinanced the mortgage (*signed refi error*).

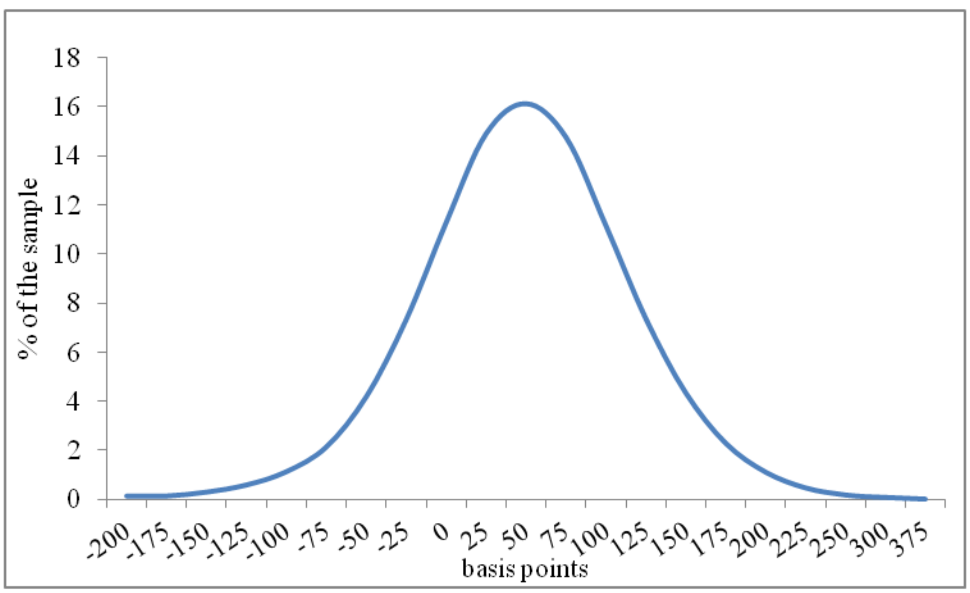


Figure 2. Example of how to calculate *Months inattention*.

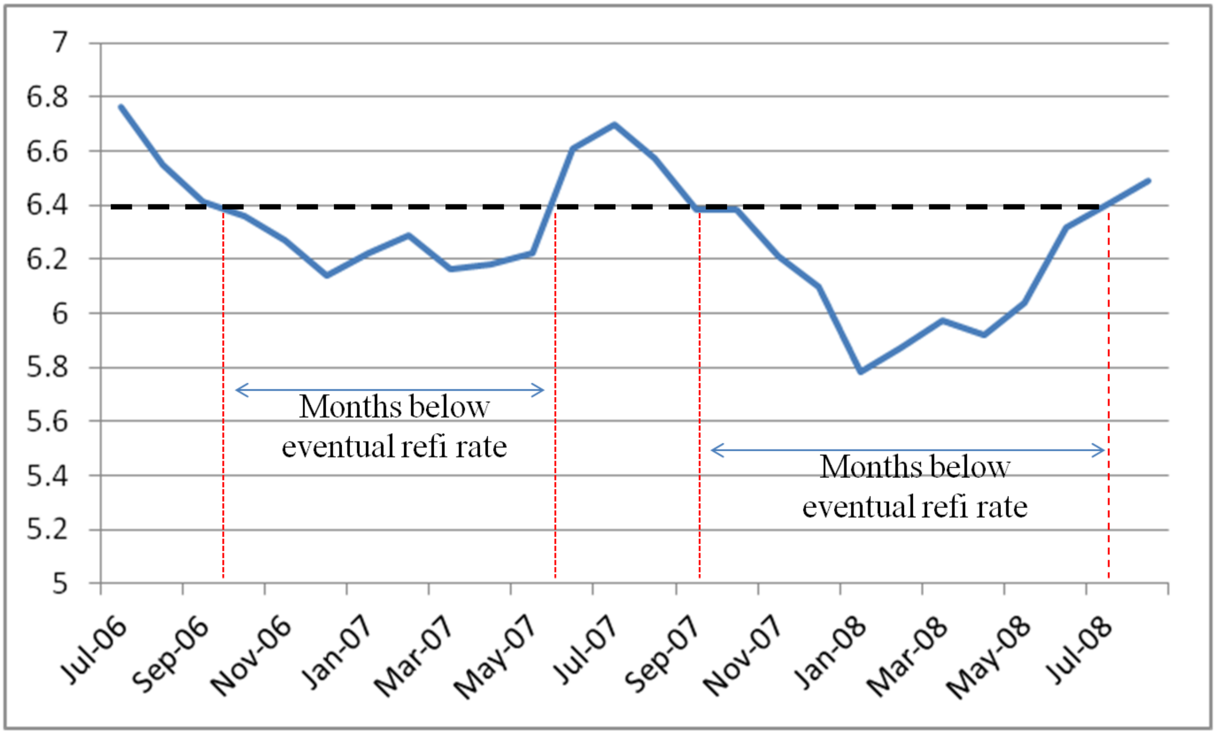
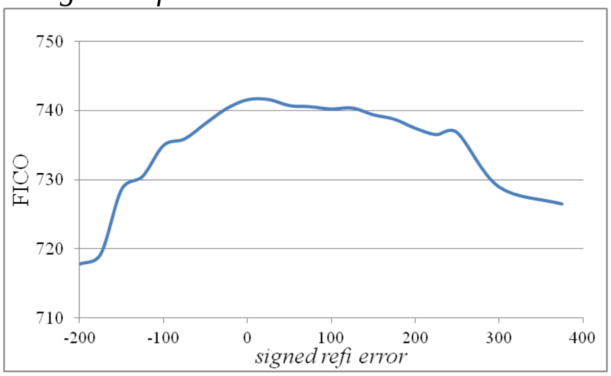


Figure 3 – Panel A: Borrower FICO scores at time of refinancing as a function *signed refi error* and *Months inattention*.

Average FICO score as a function of *signed refi error*.



Average FICO score as a function of *Months inattention.*

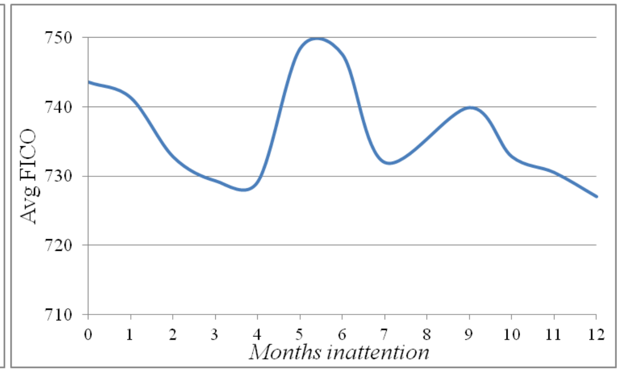
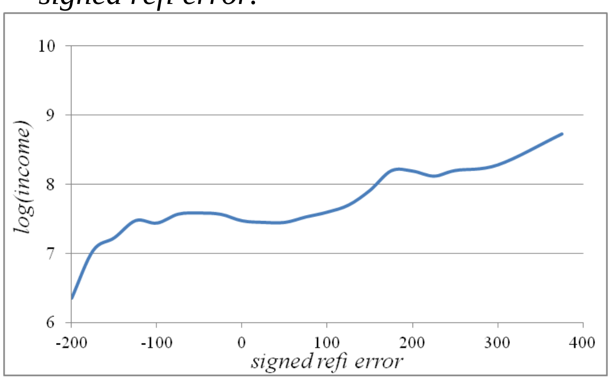


Figure 3 – Panel B: Borrower income at time of refinancing as a function *signed refi error* and *Months inattention*.

Average *log(income)* as a function of *signed refi error*.



Average *log(income)* as a function of *Months inattention.*

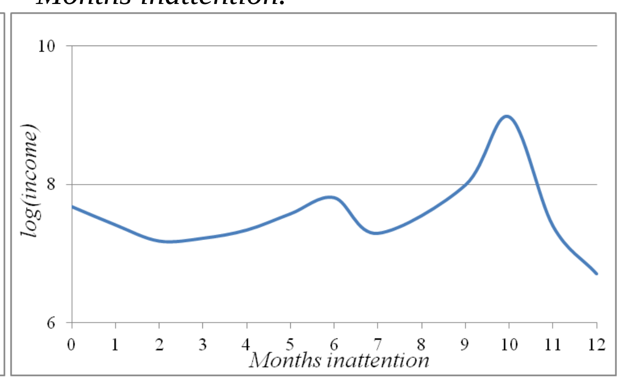
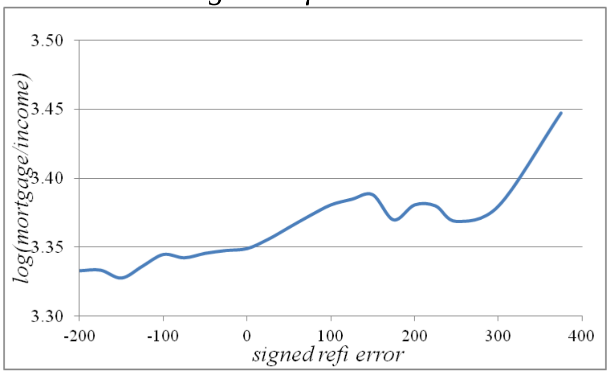
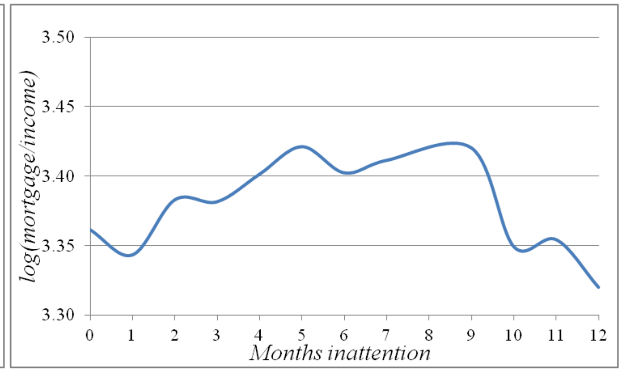


Figure 3 – Panel C: Borrower mortgage-to-income ratio at time of refinancing as a function *signed refi error* and *Months inattention*.

Average *log(mortgage/income)* as a function of *signed refi error*.



Average *log(mortgage/income)* as a function of *Months inattention.*



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