Why Do Borrowers Make Mortgage Refinancing Mistakes?*

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Abstract
Refinancing a mortgage is often one of the most important financial decisions people make. Borrowers 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. Using a unique panel data set, we find that approximately 57% of borrowers refinance sub-optimally –50% choose the wrong rate, 17% wait too long to refinance, and 10% do both. Financially sophisticated borrowers make smaller mistakes, refinancing at rates closer to optimal and waiting less after mortgage rates reach their trigger rates. Evidence suggests borrowers learn from their refinancing experiences.

Keywords: Household Finance, Mortgages, Refinance, Option Value, Financial Crisis
JEL classification: D12, D14, 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 used to purchase a home. 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; Andersen, Campbell, Meisner-Nielsen, and Ramadorai, 2014). We explore whether this is true for refis as well. 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*.[2] But, we are the first to show that households also make errors of *omission* during the refinancing process 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.[3] We examine whether these errors are related to household characteristics.

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

[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] 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).

[3] 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).

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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.[4] 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 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; henceforth, ADL) 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 they are too busy. These errors of omission have been examined for other decisions (e.g., Agarwal et al., 2007 and Korniotis and Kumarm, 2011). Some delay may be the optimal response for busy borrowers – what some refer to as rational inattention (e.g., Sims, 2003; Reis,

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

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2006). We are the first to empirically examine errors of omission in mortgage refinancing. Our analysis shows that many borrowers do not refinance immediately when their trigger rate is reached, and we 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.[5] 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 50% 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, 57% 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 are correlated with the level of financial sophistication (Amromin et al., 2011). More

[5] 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).

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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 or prepay (Hendershott and Van Order,

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1987).[6] These papers implicitly solved for the optimal refinancing differentials as solutions to partial differential equations, which were evaluated numerically. Finally, ADL derived a closed-form solution for the optimal interest rate at which to refinance from a fixed-rate mortgage to another fixed rate mortgage.[7] Their model makes several simplifying assumptions such borrowers are risk neutral and the real mortgage rate is a random walk (see the Appendix for a fuller description of the model). However, we use the ADL model to derive the optimal refi rate used in our paper because the ADL solution is transparent, tractable, and verifiable.

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 labelled "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,

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

[7] 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."

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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 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.

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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) modelled 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).[8]

[8] 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).

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The actual behavior of mortgage holders sometimes differs from the predictions of the optimal refinancing model. In the 1980s – when mortgage interest 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 refinanced too early during the period 1996–2003.[9] In addition, Agarwal, Ben-David, and Yao (2012) document that some borrowers exhibit the sunk cost fallacy in their mortgage refinancing behavior.

3. Data

We examine first-lien prime 30-year fixed-rate mortgages (FRMs) from one of the government sponsored enterprises (GSEs) that contains approximately a quarter of all national mortgage transactions originated between 1998 and 2011. All loans in our sample were then later refinanced before the end of 2011. For each mortgage, we know when the mortgage was eventually refinanced and why the borrower refinanced.[10] This allows us to focus on refis aimed toward lowering mortgage payments or rates. We also 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.

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

[9] 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).

[10] 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.

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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).[11] Our sample excludes cash-out refis (defined as those where the amount of the refi is either $2,000 or 2% greater than the remaining balance on the initial mortgage).

Our sample includes mortgages where both the initial mortgage and the refi are 30-year FRMs. By restricting the sample so that both mortgages are of the same type, we are able to focus more closely on the interest rate differential as the reason for refinancing. A unique feature of our data is that it includes information on the points and closing costs paid by a borrower. These components are essential for determining the optimal rate differential at which a borrower should refi since lenders take points and closing costs into account when setting the interest rate on a mortgage. In the raw data from which we draw our sample, 9.3% of borrowers paid points and 98% of borrowers paid closing costs for their refis. We dropped these who paid points from the sample in order to focus on refis done purely to reduce the mortgage interest rate.[12] This is something not possible with many other data sets. Finally, we drop the handful of observations where the refi rate is either more than one percentage point higher or more than four percentage

[11] In addition, a refi – even one that does not involve a cash out – can improve liquidity by extending the maturity of the debt. Borrowers that refinance a 30-year FRMs with another 30-year FRM per force extend the maturity of their mortgages. 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 main refi 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. Also, while borrowers that use a refinancing to cash out equity also care about the rate differential, their main objective is to maximize the equity extraction (Agarwal, Ben-David, and Yao, 2013).

[12] Agarwal, Ben-David and Yao (2012) show that borrowers who pay points are 22% less likely to refinance every month.

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points lower than the original (that is, previous) mortgage rate.[13] This leaves us with 271,216 refis, of which 4,882 are second refis (see Table 1 for summary statistics on our sample).[14]

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. 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 refinancing rate or, equivalently, the optimal refi rate differential (see the Appendix for more details). As noted above, the ADL model has the advantage of being tractable. The key tradeoff in the model is that a borrower locks in lower payments by refinancing but also reduces

[13] 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.
[14] We drop the small number of third and fourth refis from our sample. All results are robust to their inclusion.

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the value of refinancing in the future. Since refinancing is costly (because of closing costs), this reduces to the choice of when to exercise a costly option that buys a lower rate and a new strike price (the new mortgage rate) for refinancing in the future – essentially, refinancing today is costly and reduces the value of refinancing in the future. The ADL model yields the optimal refinancing rate as a function of the initial mortgage rate and remaining balance, closing costs on the refi, taxes, and expected future mortgage rates for 30-year FRMs. In addition to restricting attention to 30-year FRMs, one advantage of our analysis is that we know exact closing costs (unlike, e.g., Keys, Pope, and Pope, 2014). However, we do follow ADL in making assumptions about taxes and expected future mortgage rates. This may make our estimates of the optimal rate at which to refinance not perfectly precise. For this reason, we say that a borrower who refinances within 50 basis points of what we estimate as the optimal is refinancing in the "optimal range."

On average, the borrowers in our sample should have refinanced at an interest rate that was 158 basis points lower than the original (or previous) mortgage's interest rate; however, as given above, they in fact refinanced at an interest rate that averaged only 121 basis points lower (Table 1).

The difference between the optimal refi rate and the actual refi rate suggests that many 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). 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*.

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

$$optimal\ refi\ rate\ differential = optimal\ refi\ rate - initial\ mortgage\ rate,$$

and

$$refi\ error = |\Delta rate - optimal\ refi\ rate\ differential|$$

$$= |actual\ refi\ rate - optimal\ refi\ rate|$$

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

$$signed\ refi\ error = actual\ refi\ rate - optimal\ refi\ rate$$

(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 50% of borrowers refinance the optimal range, that is, within 50 basis points of the optimal rate. 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. Relatively 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, a borrower only enters our sample when a mortgage is refinancing so we do not capture the significant share of borrowers that have never refinanced, including those who have the potential for significant savings from refinancing (Fannie Mae, 2012). We return to this briefly below.

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.[15] This may not happen immediately if the borrowers do not pay careful attention to mortgage rates and thus they may

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

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miss opportunities to refinance when the mortgage rate first hits their trigger rate. When a borrower refinances after her first chance to refinance at a particular rate, we refer to this as an *error of omission*.[16]

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.[17] We measure the cost of inattention – which we refer to as *burnout* – 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,

[16] Rational inattention could explain delays of several months in refinancing. Related to this 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.

[17] 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.

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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 average mortgage rate of the month in which the borrower eventually refinanced. So, for this mortgage, the *burnout* 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. 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 borrower, and is based largely on the borrower's financial condition. The mean FICO

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score is 740 (Table 1).[18] We expect that a higher FICO is associated with a more sophisticated borrower.[19] The mean monthly income of borrowers in our sample is $7,570 (measured at the time of the refi). Since the distribution of income is skewed, we use the log of income in our analysis.[20] We suspect that higher income borrowers are more sophisticated but they may also be busier, giving them less time to monitor mortgage rates.

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 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.

We hypothesize that *burnout* 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:

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

If we are correct, *burnout* 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 eventual rate at which the borrower refinances (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,

[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 more 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.

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we use the relationship between *burnout* and the average error between the trigger rate and the ERR. However, because *burnout* can be related to financial sophistication, we only want to use the information in the *burnout* variable that does not reflect sophistication. So, we take the residual from (1) – *burnout residual* - and include it as a control. This gives us a baseline specification of:

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

We include the year of loan origination, the year when a loan is refinanced, and state dummies as control for cohort and other macro events and trends in (1) and (2).[21]

We estimate the system (1) and (2) using three-stage least squares (3SLS). The 3SLS incorporates the serial correlation between the errors in burnout equation and the refi error equation.[22]

4.1 Baseline 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 eventual refi rate 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 *

[21] In an unreported analysis, we included more controls for the interest rate environment and recent history as well as controls for mortgage and housing price conditions in the borrower's local market. The coefficients on our key independent variables in that analysis are qualitatively similar to those reported here.

[22] It is implemented in three steps: predict burnout using independent variables; use 2SLS to get the residuals to estimate the cross-equation correlation matrix; and determine the final 3SLS that incorporates the correlation matrix.

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(0.800 – 0.700) = –0.34), or about 13% of the sample's average *burnout.* 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 average *burnout*.

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 burnout, 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 1.67 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. *Burnout residual* is the residual from the *burnout* regression (1). As explained earlier, it measures the inattention not explained by our measures of financial sophistication and mortgage importance to

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a borrower. The positive and significant coefficient on *burnout residual* in the second column of Table 2 is consistent with borrowers who are more inattentive making larger refinancing errors.

4.2 Repeat Refinancing

Borrowers can learn from repeated financial decision making (Agarwal, et al., 2014). 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 less *burnout* (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 burnout and refi error stages. Since the regressions include time dummies that control for general changes in the ease of refinancing over time, our results suggest that borrowers may 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.

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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. Sample Selection Issues

The model in Sections 4.1 and 4.2 illustrates the relationship among financial sophistication, mortgage importance, and errors of omission and commission for borrowers that refinance their mortgage. However, some borrowers never refinance their mortgages even when it is optimal for them to do so (and some will do so after the sample period ends). A borrower that does not refinance is not included in the analysis. This introduces two sample selection issues. First, borrowers may fail to refinance because they are unable to do so. This will be more common when borrower income is low or when a mortgage is large relative to the home's value. Still, we expect that these effects would be small. One way to test this is to examine cases where borrowers are likely to be able to easily refinance their loans. So, we look at borrowers with a low loan-to-value (LTV) ratio and at the housing boom prior to the decline in home prices that occurred in the financial crisis.

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

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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%.[23] 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 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 4 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 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 period prior to the crisis, home prices were generally increasing quickly and mortgages were easy to get even for subprime borrowers (in part because of the presence of private securitization markets). Thus, the inability to refinance was likely to be less of an issue than it might have been during the financial crisis. For this reason, and 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 4. For the burnout regression, the coefficient on the mortgage-to-income ratio is more negative in the non-crisis sample than it is in the full sample results in Table 2. This is consistent with borrowers having a high mortgage-to-income ratio being more able to refinance when they want

[23] 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.

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pre-crisis than during the crisis. However, the coefficient on the income variable is also more negative in the non-crisis sample than it is in the full sample, inconsistent with low income borrowers being more constrained during the crisis. Also, note that while most of the results for the pre-crisis sample are qualitatively similar to the full sample results, the sign of the burnout residual coefficient changes. This suggests that the refi errors made by inattentive borrowers change over time. Below, we show that this may be due to a particular and small fraction of refinancings.

Together, the regressions in Table 4 suggest that our results are not being driven by the first selection problem, that is, the inability of some borrowers to refinance – especially less sophisticated ones – when they want to. But there is also a second selection problem. Some borrowers may never want to refinance even if our model suggests it is beneficial for them. Keys, Pope, and Pope (2014) find that at the end of 2010, refinancing was both optimal and feasible for 20% of borrowers.[24] Borrowers that never refinance even if it is optimal make large errors of omission and commission but they are not in our sample. There is no way to get at this directly in our framework – we have a maintained assumption that the borrowers that never refinance are not more sophisticated than those that refinance – but we can shed light on it by comparing the characteristics of borrowers that never refinance to those that do. In Table 5, we take all 30-year fixed-rate mortgages between 1998 and 2011 from the same GSE that provided our sample data and look five years out from the origination of the mortgages (or to the end of 2013). We want to compare borrowers that do not refinance to those that refinance for payment-oriented reasons (these are the type of refinancings in our sample). Because we can only trace mortgages that are guaranteed by the same entity, we organize the mortgages into the following

[24] Unfortunately, Keys, Pope, and Pope (2014) do not calculate how long refinancing was in the money for these borrowers. Our burnout results suggest there is often a short delay between refinancing becoming optimal and the typical borrower refinancing.

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four groups. Mortgages that have not been refinanced, mortgages refinanced back to the same entity where the refi includes a cash out, mortgages refinanced back to the same entity to lower the payment or interest rate (we refer to these as rate/term refis), and others (which includes loans repaid without refinancing, loans that default, and loans refinanced to another entity). As shown in the table, borrowers that do payment refis have larger FICOs, higher incomes, and larger mortgage-to-income ratios than borrowers that never refinance.[25] This suggests that if we could somehow include borrowers that have never refinanced when rates were at or below their optimal refinancing rate, it would only strengthen our finding that borrowers make smaller errors when they are more sophisticated and when mortgages are more important. However, the results in Table 5 (and Keys, Pope, and Pope, 2014) suggest we may substantially underestimate the share of borrowers that do not refinance when they should so we only capture the only who eventually refinance after some burnout period. For completeness, Table 5 also includes cash-out refis. The data suggest that cash-out refinancers are less sophisticated than those that do payment refis.

Another way to address the sample selection problems is to split the borrowers in our sample by whether they refinance at a rate above or below the optimal rate. Borrowers that refinance at a rate below the optimal rate may do so because they do not pay attention to the option to refinance, and thus may share more in common with borrowers that do not refinance than do borrowers that refinance at a rate above the optimal rate. As the data in Table 1 show, a substantially larger share of refis is at a rate well above the optimal rate than the share that is

[25] These results are broadly consistent with Keys, Pope, and Pope (2014). They find low FICO and (weakly) low income borrowers are more likely to have a mortgage for which refinancing is optimal. They do not directly examine the mortgage-to-income ratio but find that borrowers with a high FICO and low mortgage loan-to-house value ratio – possibly indicating a low mortgage-to-income ratio – are less likely to have a mortgage for which refinancing is optimal. Note that we are comparing mortgages that are *have been* refinanced to mortgages that *have not been* refinanced. Keys, Pope, and Pope are comparing mortgages that *should be* refinanced to those that *should not be* refinanced but they do not examine mortgages that have been refinanced.

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well below the optimal rate. We split the sample into those borrowers who refinance at a rate at least 50 basis points above 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 (we refer to them as "woodheads" or WH borrowers in the spirit of prior literature), and other borrowers which we say refinance in the optimal range (OR borrowers). Roughly 50% of the observations are in the optimal range.[26] Of those that are not, IF borrowers outnumber WH borrowers by a ratio of five to one. Note that for WH borrowers, the option to refinance is in the money according to our estimate of the option value while for IF borrowers the option is not in the money.

The borrowers in the three groups are similar in their characteristics. The mean of FICO scores, log(mortgage/income), and log(income) all differ by less than 2% across the groups (Table 6). 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.

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 burnout 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 burnout stage of the regression. There is no significant impact of mortgage importance for the other groups of borrowers.

[26] 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.

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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 *burnout 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.[27] One might argue that refinancing at a rate less than what we call the optimal rate is in fact better than refinancing at what we call the optimal rate because the borrower gets a lower interest rate. This could be true if the borrower had reason to expect rates to fall (rather than getting lucky through inattention). We explore this in the next section.

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).

4.4. Robustness

The results above 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.

Many mortgages, especially including refinancings, are done with the assistance of a broker. In many cases, a broker will call a household to induce them to refinance. The broker may also assist the household with the paperwork and other elements of the refinancing process. This

[27] Alternatively, WH borrowers may suffer burnout because they are unable to get a new mortgage when they first try.

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suggests that refis placed by brokers may look different than those made without the assistance of a broker. In our sample, 41.6% of refis used a broker. Brokered refis occur an average of eight months faster than non-brokered refis and with 0.64 months less burnout, consistent with brokers prompting households to refinance. Given this, one might expect that *Δrate* – the difference between the refi and initial mortgage rates – would be much smaller for brokered mortgages. There is an eight basis point difference between *Δrate* for brokered and non-brokered refis. However, this does not translate to a large difference in the refi error between the two groups. This is because the optimal refi rate differential is smaller for households that have brokered refis, mostly because these households have larger incomes than households that have non-brokered refis. Interestingly, the average FICO score is essentially the same across the two groups as is the share of refis with closing costs.

A broker must sell a household on a refinancing. One way to do so is to give a rule of thumb. As Figure 3 shows, brokers seem to focus disproportionately on a 50 basis point rate differential as the time to refinance. The distribution of *Δrate* for brokered and non-brokered refis is similar except for the bulge near 0.50%. Because of this and the other differences between brokered and non-brokered refis, we run our baseline regressions to see whether errors of omission and commission are different for the two types of refis.

Table 8 presents results for the baseline regression when the sample is split into brokered and non-brokered refis. The results are qualitatively similar. The coefficients have the same signs across the regressions and the key variables are statistically different from zero for both groups of refis. The only major quantitative difference is for the coefficient on the FICO score in the refi error regressions. FICO score matters a lot more for brokered refis than for non-brokered refis. This may be a function of attentiveness. Households contacted by brokers should be more

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aware of refinancing opportunities than households that are not contacted. This increases the premium on financial sophistication, as we find in our results.

The cost of an error of omission is related to the potential benefits forgone. That is why we measure *burnout* 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. An alternative measure of the cost of inattention, *cumulative loss*, is

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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 *cumulative loss* rather than *burnout* does not change the qualitative conclusions of our analysis (results not shown).

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 can include additional independent variables exploring whether refinancing behavior is affected by expectations, local market conditions, and behavioral factors without qualitatively changing the predicted effects of FICO, income, and the mortgage-to-income ratio on refinancing. In particular, we introduced controls for the slope of the yield curve (as a forecast of future interest rates), recent behaviour of interest rates (moves up and down to see whether they affect borrower psychology; see Michenaud and Solnik, 2008), and local conditions in mortgage and housing

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markets. While all of these variables significantly affect refinancing decisions, the do not affect the significance or signs of our key coefficients (results not shown).

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 50% 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).

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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.

Although borrowers refinance inefficiently with respect to their private incentives, the results here should not be taken to suggest that reducing errors of omission or commission would improve welfare. Our analysis takes as given the mortgage contract – a 30-year fixed-rate loan with no prepayment penalty. It is certainly possible that the optimal prepayment for borrowers using this contract is not socially optimal (Mayer, Piskorskiz, and Tchistyi, 2013). The only thing we show is that, given the 30-year fixed-rate mortgage contact, borrowers could improve their own welfare by better refinancing choices. Our results have policy implication as outlined in Campbell, Jackson, Madrian, and Tufano (2011).

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Appendix: Optimal refinancing rate

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

$$\Delta r^* = \quad - \qquad \text{(X1)}$$

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

$$= \quad , \qquad \text{(X2)}$$

$$= \quad , \qquad \text{(X3)}$$

where 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 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),

$$= \qquad \text{(X4)}$$

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), and the probability of moving (10%). We set the transactions cost of refinancing (κ) equal to the actual closing paid by the borrower (ADL use an estimate for this cost in their paper).

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Table 1. Summary statistics.

Summary statistics based on 30-year FRM that refinance to a 30-year FRM where both mortgages are originated between 1998 and 2011. To be in the sample, mortgages must 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): abs(*Δrate* – optimal rate)	59.80	45.52	50.26
Months from origination to refinance	28.32	21.94	22.00
Burnout: months of missed refi opportunities	2.66	4.10	1.00
FICO	740	52	751
Borrower income at refi ($1000s, monthly)	7.57	6.60	6.50
Log(income)	8.77	0.54	8.78
Mortgage size ($1000s)	203.19	95.99	184.00
Mortgage-to-income ratio	31.45	13.33	28.88
Log(mortgage/income)	3.36	0.41	3.36
Second refi dummy	0.02	0.13	0.00
Closing cost dummy	0.98	0.13	1
Average closing cost ($)	3,606	2,463	3,076
Refi is brokered	0.41	0.27	0.00
Refi year	2006	4	2009

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Table 2. Baseline regression results.

Results based on 3SLS regression where the dependent variables are *burnout*, 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	
	burnout	*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)
Burnout residual		0.235**
		(2.96)
Observations	271,216	
Adjusted R-squared	0.223	0.162

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Table 3. Regression results including control for second refinancings.

Results based on 3SLS regressions where the dependent variables are *burnout*, 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	
	burnout	*refi error*	*burnout*	*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)
Burnout 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	271,216		9,764	
Adjusted R-squared	0.183	0.160	0.162	0.168

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Table 4. 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 *burnout*, 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%		Excluding the financial crisis	
	burnout	*refi error*	*burnout*	*refi error*
FICO/1000	-3.472***	-17.094***	-2.602***	-15.960***
	(-19.27)	(-8.17)	(-13.53)	(-6.92)
Log(mortgage/income)	-0.376***	-13.052***	-0.417***	-12.121***
	(-12.61)	(-38.15)	(-10.62)	(-25.82)
Log(income)	-0.391***	-11.435***	-0.414***	-11.476***
	(-16.74)	(-42.36)	(-13.19)	(-30.27)
burnout residual		0.169		-1.523***
		(1.65)		(-7.55)
Second refinancing dummy	-0.392***	-11.369***	0.037	-8.667***
	(-6.44)	(-16.36)	(0.41)	(-8.33)
Observations	188,931		121,367	
Adjusted R-squared	0.237	0.185	0.304	0.138

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Table 5. Borrowers characteristics for mortgages five years after origination.

For all 30-year fixed-rate mortgages from the proprietary data between 1998 and 2011, this table reports the status of the mortgage five years after origination or at the end of 2013, whichever comes first. Active mortgages are those that have not been repaid (including by refinance) and have not defaulted, payment refi mortgages are those that are refinanced back to the same entity where there is no cash out, cash-out refinancing mortgages are those refinanced back to the same entity with a cash out, and other includes all other mortgages (loans repaid without refinancing, loans that default, and refinancing to a mortgage by other entities). Standard errors are in parentheses.

Variable	Percent of observations	FICO	Log(income)	Log(mortgage /income)
Active mortgages	31%	727 (60.7)	8.61 (0.60)	3.19 (0.54)
Rate/term refi mortgages	21%	734 (53.5)	8.79 (0.56)	3.31 (0.45)
Cash-out refi mortgages	9%	717 (56.8)	8.65 (0.54)	3.21 (0.48)
Other	39%	720 (59.7)	8.66 (0.59)	3.20 (0.52)
Total	43,970,244	724	8.67	3.22

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Table 6. Summary statistics for itchy finger, woodhead, and optimal refinancing.

Summary statistics based on 30-year FRM that refinance to a 30-year FRM where both mortgages are originated between 1998 and 2010. To be in the sample, mortgages must not be used to cash out equity. Itchy finger (IF) refinancings are those that occur at greater than 50 basis points above the optimal rate. Woodhead (WH) refinancings are those that occur at greater than 50 basis points below the optimal rate. All other refinancings are in the optimal range (OR).

	Refinancing type		
Variable	Itchy Fingers	Optimal Refinancers	Woodheads
Δrate: Interest rate difference (refi rate – initial mortgage rate, in BP)	-91.87	-134.27	-186.17
Optimal refi rate differential (BP)	-188.65	-142.01	-99.25
refi error (BP)	96.78	24.15	86.91
Months from origination to refinance	27.61	28.16	32.78
burnout	3.11	2.34	2.31
FICO	0.740	0.741	0.736
Borrower income at refi ($1000s)	7.69	7.47	7.50
Log(income)	8.77	8.77	8.78
Mortgage size ($1000s)	205.69	201.68	199.76
Mortgage-to-income ratio	29.33	28.67	28.20
Log(Mortgage/income)	3.38	3.36	3.34
Second refi dummy	0.015	0.020	0.019
Closing cost dummy	1.00	0.99	0.85
Average closing cost ($)	4,844	2,895	1,685
Observations	113,204	134,968	23,044

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Table 7. Split of borrowers by errors of commission.

Results based on 3SLS regression where the dependent variables are *burnout*, 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.

	Itchy Fingers	Optimal Refinancers	Woodheads
Burnout			
FICO/1000	-4.141***	-2.878***	-3.207***
	(-16.82)	(-15.89)	(-7.53)
Log(mortgage/income)	-0.298***	0.033	0.140
	(-6.96)	(1.05)	(1.82)
Log(income)	-0.379***	-0.023	0.044
	(-11.29)	(-0.95)	(0.72)
Second refinancing dummy	-0.608***	-0.202**	-0.143
	(-6.06)	(-3.22)	(-0.89)
Adjusted R-squared	0.267	0.1939	0.1969
refi error			
FICO/1000	-8.880***	-2.058*	-33.883***
	(-4.04)	(-2.50)	(-7.45)
Log(mortgage/income)	-10.314***	-0.982***	-2.017*
	(-27.61)	(-6.94)	(-2.49)
Log(income)	-8.474***	-0.801***	-2.709***
	(-28.66)	(-7.22)	(-4.20)
Burnout residual	0.081	-0.019	0.696***
	(0.76)	(-0.50)	(3.41)
Second refinancing dummy	-7.116***	-1.148***	6.821***
	(-8.13)	(-4.08)	(4.04)
Observations	113,204	134,968	23,044
Adjusted R-squared	0.137	0.011	0.028

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Table 8. Baseline regression results split by brokered and non-brokered refis.

Results based on 3SLS regression where the dependent variables are *burnout*, 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. A brokered refi is one where a mortgage brokered is reported to be used. The regression has state fixed effects, origination year fixed effects, and refi year fixed effects. Robust standard errors in parentheses.

	Brokered refis		Non-brokered refis	
	burnout	*refi error*	*burnout*	*refi error*
FICO/1000	-3.260***	-22.102***	-2.753***	-6.201**
	(-14.72)	(-8.03)	(-15.48)	(-2.97)
Log(mortgage/income)	-0.293***	-10.238***	-0.154***	-12.548***
	(-7.82)	(-22.18)	(-4.89)	(-34.21)
Log(income)	-0.332***	-10.095***	-0.240***	-9.911***
	(-11.43)	(-28.11)	(-9.67)	(-34.24)
burnout residual		0.821***		0.665***
		(7.32)		(9.39)
Second refinancing dummy	-0.354***	-10.621***	-0.259***	-8.570***
	(-5.14)	(-12.53)	(-3.47)	(-9.85)
Observations	112,855		158,361	
Adjusted R-squared	0.291	0.158	0.236	0.185

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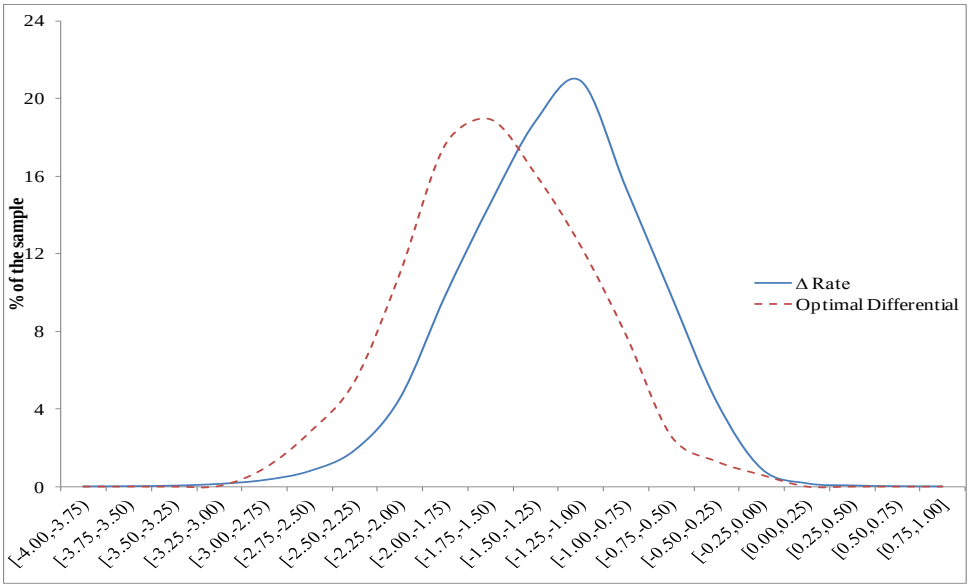
Figure 1.

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*).

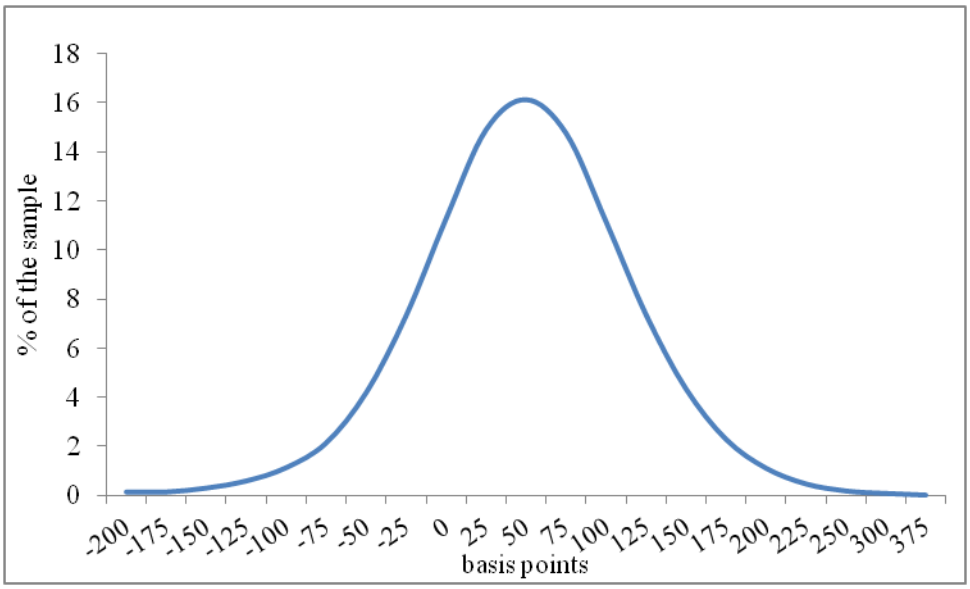


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Figure 2. Example of how to calculate *burnout*.

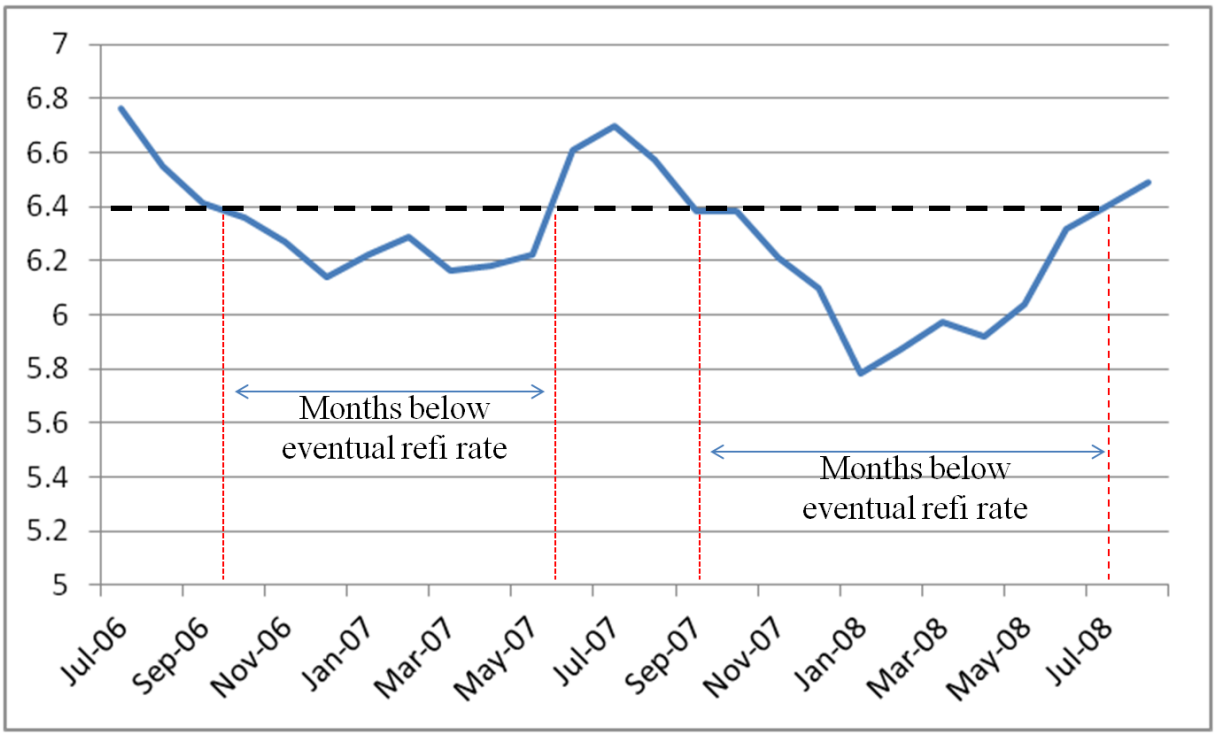

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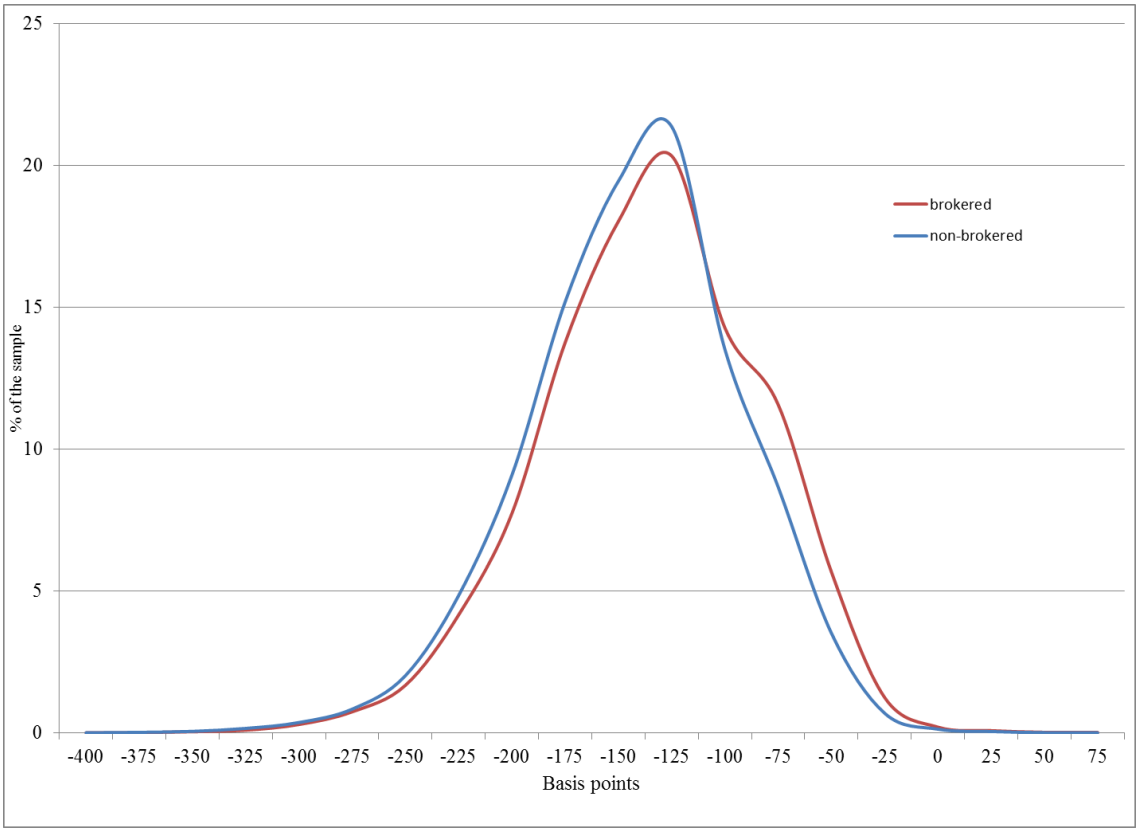
Figure 3. Difference between the interest rate on a mortgage that has been refinanced and the interest rate on the initial mortgage (Δ*rate*), for brokered and non-brokered refis.



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