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Why Do Borrowers Make Mortgage Refinancing Mistakes?

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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 simple closed-form solution approximation of the optimal refinancing rule and a unique panel data set including information from a large secondary market participant on refinancing, we find that approximately 57% of borrowers refinance suboptimally—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
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1. Introduction

Refinancing a mortgage is as American as apple pie. Over the period 2000–2009, 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 et al. 2011, Andersen et al. 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 et al. 2011)—what we call an error of *commission*.[2] But, to our knowledge, 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. It is important to focus on both errors of commission and errors of omission when thinking about the costs of suboptimal financial decision making.[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 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

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

[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 et al. 2009). More broadly, it is puzzling that less than 30% of U.S. households directly participate in equity markets (Cole and Shastry 2009, Li 2014), 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 a 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 et al. 2012).

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 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 refinance today rather than in the future (Agarwal et al. 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 also that she take the actions necessary to refinance (such as contacting a broker or bank and completing paperwork). Agarwal et al. (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, 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). To our knowledge, 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 to reduce mortgage payments. Our sample does not include borrowers who refinance 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 refinance 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, and 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 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—see, e.g., Keys et al. (2010), Ben-David (2011), and Jiang et al. (2014).

The rest of the paper is organized as follows. In §2, we review the literature, and in §3, we provide a description of the data we use. The main results are presented in §4. Finally, we present our conclusions in §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, b). 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 1987).[6] These papers implicitly solved for

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

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

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

the optimal refinancing differentials as solutions to partial differential equations, which were evaluated numerically. Finally, Agarwal et al. (2012) derive 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 online appendix, available as supplemental material at https://doi.org/10.1287/mnsc.2015.2272, 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. 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 puzzles, 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 et al. (2005) allow variations in housing price to affect prepayment of mortgages. In hazard rate estimates of prepayment of mortgages, LaCour-Little (1999) and Bennett et al. (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 refis where consumption smoothing plays a major role, so we restrict our attention to refis where there is at most a 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 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 et al. (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. We extend the approach in LaCour-Little 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.

An alternative reason why borrowers may delay refinancing is that they do not always monitor mortgage rates closely. The idea that people may only make decisions infrequently has long been used by economists to explain apparent deviations from optimal behavior. Calvo (1983) models 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 et al. (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]

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

[7] Agarwal et al. (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.

[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 (Della and Pollet 2009). In addition, investors tend to be net buyers of stocks that are in the news more (Barber and Odean 2008).

Yavas (2009) have noted that some borrowers refinanced too early during the period 1996–2003.[9] In addition, Agarwal et al. (2012) document that some borrowers exhibit the sunk cost fallacy in their mortgage refinancing behavior. Agarwal et al. (2014b) also show that individuals that pledge higher collateral have a lower hazard to default, although they have similar prepayment hazards and credit card delinquency.

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 at lowering mortgage payments or rates. We also know whether 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 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 they include 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 refinance 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 those who paid points from the sample 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 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 (see Table 1). But

[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 et al. (2000, 2001), Hurst (1999), Downing et al. (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 resulting from a fuzzy matching process using a series of variables.

[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 FRM with another 30-year FRM perforce 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 online 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, although 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 et al. 2015).

[12] Agarwal et al. (2012) show that borrowers who pay points are 22% less likely to refinance every month.

[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.

Table 1 Summary Statistics

Variable	Mean	SD	Median
Δ*rate*: 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(Δ*rate* − 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 ($1,000s, monthly)	7.57	6.60	6.50
log(*Income*)	8.77	0.54	8.78
Mortgage_size ($1,000s)	203.19	95.99	184.00
Mortgage-to-income_ratio	31.45	13.33	28.88
log(*Mortgage/Income*)	3.36	0.41	3.36
Second_refi_dummy	0.02	0.13	0.00
Closing_cost_dummy	0.98	0.13	1
Average_closing_cost ($)	3,606	2,463	3,076
Refi_is_brokered	0.41	0.27	0.00
Refi_year	2006	4	2009

Notes. Summary statistics based on a 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. BP, basis points.

there is a wide distribution in Δ*rate* in the sample (see panel A of Figure 1). Many borrowers refinance when the rate differential is 25 basis points or less, whereas others do not refinance 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 Agarwal et al. (2012) to estimate the optimal refinancing rate or, equivalently, the optimal refi rate differential (see the online appendix for more details). As noted above, the ADL model has the advantage of being tractable. The key trade-off in the model is that a borrower locks in lower payments by refinancing but also reduces 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—in essence, 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 et al. 2014). However, we do follow Agarwal et al. 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 (see 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 et al. 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*.

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

$$\begin{aligned} &optimal\_refi\_rate\_differential \\ &\quad = optimal\_refi\_rate - initial\_mortgage\_rate \end{aligned}$$

and

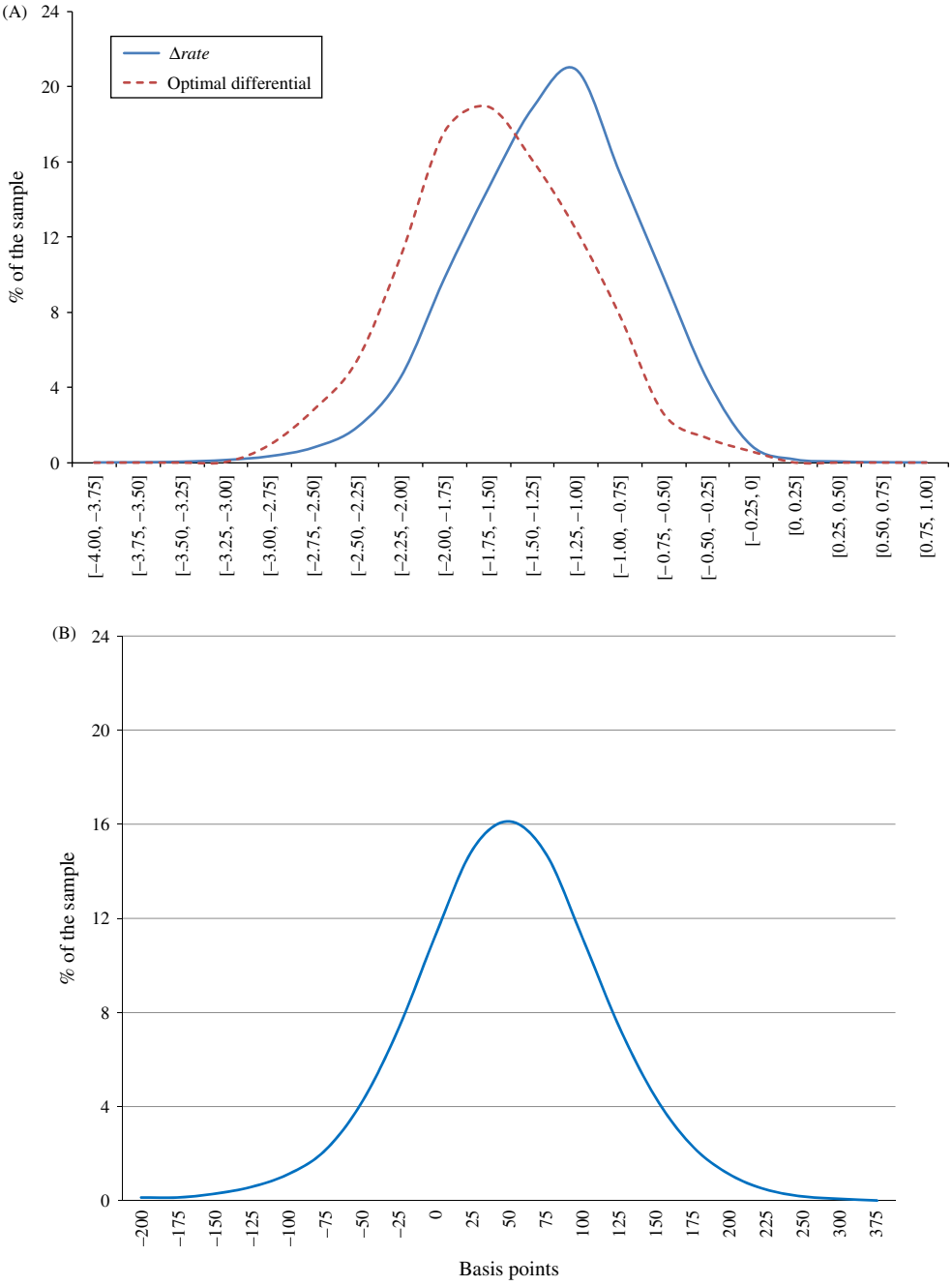
$$\begin{aligned} refi\_error &= |\Delta rate - optimal\_refi\_rate\_differential| \\ &= |actual\_refi\_rate - optimal\_refi\_rate|, \end{aligned}$$

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

$$\begin{aligned} &signed\_refi\_error = \\ &\quad actual\_refi\_rate - optimal\_refi\_rate \end{aligned}$$

(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 within 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, although lower than the rate of their existing mortgage, is not different enough to make up for the costs of refinancing, including the forgone option to refinance if rates fall slightly in the future. Relatively

Figure 1 **(Color online) Difference Between the Interest Rate on a Mortgage That Has Been Refinanced and the Interest Rate on the Initial Mortgage (Δ*rate*) (Panel A) and 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*) (Panel B)**



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 miss opportunities to refinance when the mortgage rate first hits their trigger rate. When a borrower

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

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 his or her 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.[18] 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 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 whether certain borrower, mortgage, and market characteristics are associated with suboptimal repayment—measured by refinancing either at the wrong mortgage rate or at the wrong time—more likely. Although 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 score is 740 (see Table 1).[19] We expect that a higher FICO is associated with a more sophisticated borrower.[20] 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.[21] We suspect that higher income borrowers are more sophisticated but 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,

[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 as an option means that having a longer time between observations is similar to 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.

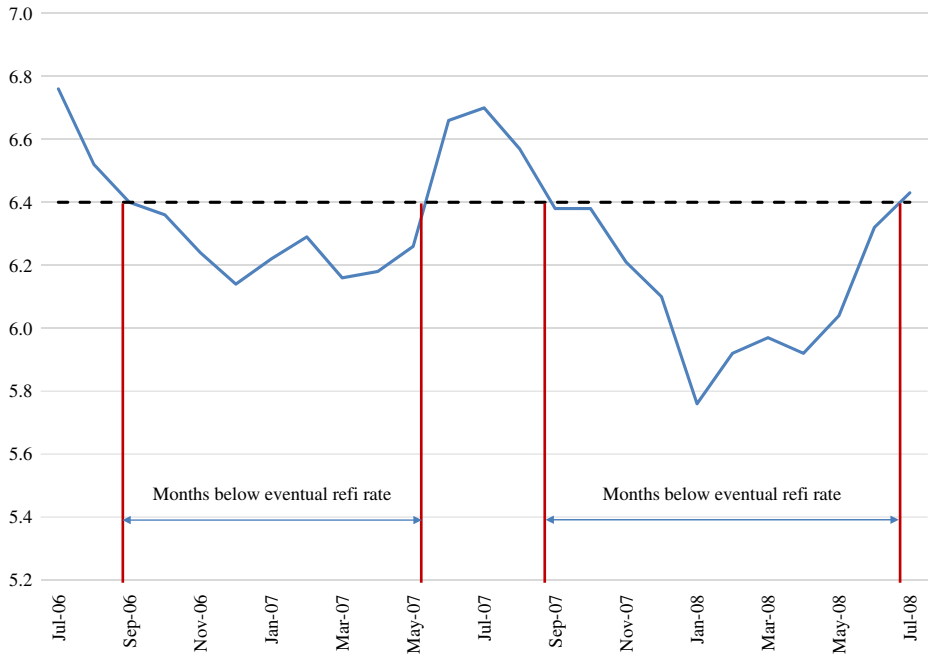
[18] Burnout does not factor in the degree to which the average mortgage rate falls below the average mortgage rate at the time of refinancing; it only accounts for the period of inattention. Our results are robust alternative measures of inattention (see the online appendix for one example).

[19] 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.

[20] 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 incomes were more likely to take out complex mortgages.

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

Figure 2 **(Color online) Example of How to Calculate Burnout**



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

$$burnout = f(FICO, \log(income), \log(mortgage/income), other\_controls). \quad (1)$$

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, 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

$$refi\_error = f(FICO, \log(income), \log(mortgage/income), burnout\_residual, other\_controls). \quad (2)$$

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).[22]

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.[23]

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 FICO score of 800 to 700, all else being equal, indicates an increase

[22] 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.

[23] It is implemented in three steps: predict burnout using independent variables, use two-stage least squares to get the residuals to estimate the cross-equation correlation matrix, and determine the final 3SLS that incorporates the correlation matrix.

Table 2 Baseline Regression Results

	Dependent variable	
	Burnout	*Refi_error*
FICO/1,000	−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^2	0.223	0.162

Note. 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 are in parentheses.

*** and ** indicate statistical significance at the 1% and 5% levels, respectively.

of 0.34 months in waiting time ($-3.418 \times (0.800 - 0.700) = -0.34$), 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 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. 2014b). The decision about when refinancing is correct is complicated (Agarwal et al. 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 (by 16 points) and larger incomes (by 13%) 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 1 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.

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

Table 3 Regression Results Including Control for Second Refinancings

	Full sample		Borrowers with two refis only	
	Burnout	*Refi_error*	*Burnout*	*Refi_error*
FICO/1,000	−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^2	0.183	0.160	0.162	0.168

Notes. 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 are in parentheses.

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

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 §§4.1 and 4.2 illustrates the relationship among financial sophistication, mortgage importance, and errors of omission and commission for borrowers that refinance their mortgages. 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.

The first sample selection issue is that 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. Some borrowers, including those with a large LTV, may be unable to qualify for a new loan when mortgage rates first hit their ERR. We find that borrowers with a LTV below 80%, who are unlikely to have trouble refinancing, make mistakes that are qualitatively similar to those for the full sample of borrowers (see the online appendix for details). 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. To ensure that crisis effects are not driving our results, we run our baseline specification for the period 1998–2006. The results suggest that our findings are not driven by the crisis (see the online appendix for details).[24]

The second selection problem is that some borrowers may never want to refinance even if our model suggests it is beneficial for them. Keys et al. (2014) find that at the end of 2010, refinancing was both optimal and feasible for 20% of borrowers.[25] 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 4, we take all 30-year fixed-rate mortgages between 1998 and 2011 from the same GSE that provided our sample data and look five

[24] Although most of the results for the precrisis 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 refis.

[25] Unfortunately, Keys et al. (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.

Table 4 Borrower Characteristics for Mortgages Five Years After Origination

Variable	% of observations	FICO	log(*Income*)	log(*Mortgage*/*Income*)
Active_mortgages	31%	727	8.61	3.19
		(60.7)	(0.60)	(0.54)
Rate/term_refi_mortgages	21%	734	8.79	3.31
		(53.5)	(0.56)	(0.45)
Cash-out_refi_mortgages	9%	717	8.65	3.21
		(56.8)	(0.54)	(0.48)
Others	39%	720	8.66	3.20
		(59.7)	(0.59)	(0.52)
Total	43,970,244	724	8.67	3.22

Notes. 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, *rate/term_refi_mortgages* are those that are refinanced back to the same entity where there is no cash-out; *cash-out_refi_mortgages* are those refinanced back to the same entity with a cash-out; and *others* includes all other mortgages (loans repaid without refinancing, loans that default, and refinancing to a mortgage by other entities). Standard errors are in parentheses.

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 refis in our sample). Because we can only trace mortgages that are guaranteed by the same entity, we organize the mortgages into the following 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 (including 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 FICO scores, higher incomes, and larger mortgage-to-income ratios than borrowers that never refinance.[26] 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 4 (and Keys et al. 2014) suggest that 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 4 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 they 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 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.[27] Of those that are not, IF borrowers outnumber WH borrowers by a ratio of 5 to 1. Note that for WH borrowers, the option to refinance is in the money according to our estimate of the option value, although for IF borrowers, the option is not in the money.

The borrowers in the three groups are similar in their characteristics. The means of *FICO*,

[26] These results are broadly consistent with Keys et al. (2014). They find low FICO scores 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 score 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 *have been* refinanced to mortgages that *have not been* refinanced. Keys et al. are comparing mortgages that *should be* refinanced to those that *should not be* refinanced, but they do not examine mortgages that have been refinanced.

[27] 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.

Table 5 Summary Statistics for Itchy Finger, Woodhead, and Optimal Refinancing

	Refinancing type		
Variable	IF	OR	WH
Δ*rate* (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 ($1,000s)	7.69	7.47	7.50
log(*Income*)	8.77	8.77	8.78
Mortgage_size ($1,000s)	205.69	201.68	199.76
Mortgage-to-income_ratio	29.33	28.67	28.20
log(*Mortgage*/*Income*)	3.38	3.36	3.34
Second_refi dummy	0.015	0.020	0.019
Closing_cost dummy	1.00	0.99	0.85
Average_closing_cost ($)	4,844	2,895	1,685
Observations	113,204	134,968	23,044

Notes. Summary statistics based on a 30-year FRM that is refinanced 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) refis are those that occur at greater than 50 basis points above the optimal rate. Woodhead (WH) refis are those that occur at greater than 50 basis points below the optimal rate. All other refis are in the optimal range (OR). BP, basis points.

log(*Mortgage*/*Income*), and log(*Income*) all differ by less than 2% across the groups (see Table 5). 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 6.

Errors of omission are decreasing with an increase in the level of financial sophistication for all three groups of borrowers. The coefficients on *FICO* 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 log(*mortgage*/*income*) 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.

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 *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 on optimal refinancing opportunities when rates first hit their trigger rates.[28] 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 discuss additional factors that may affect the decision to refinance.

Many mortgages, especially refis, 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 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. A broker must sell a household on a refinancing. One way to do so is to give a rule of thumb. As

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

Table 6 Split of Borrowers by Errors of Commission

	IF	OR	WH
Burnout			
FICO/1,000	−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^2	0.267	0.1939	0.1969
Refi_error			
FICO/1,000	−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^2	0.137	0.011	0.028

Notes. 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 borrowers are those who refinance within 50 basis points of optimal. The IF borrowers are those that refinance at a rate that is more the 50 basis points larger than the optimal rate, and the WH borrowers are those that refinance 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 are in parentheses.

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

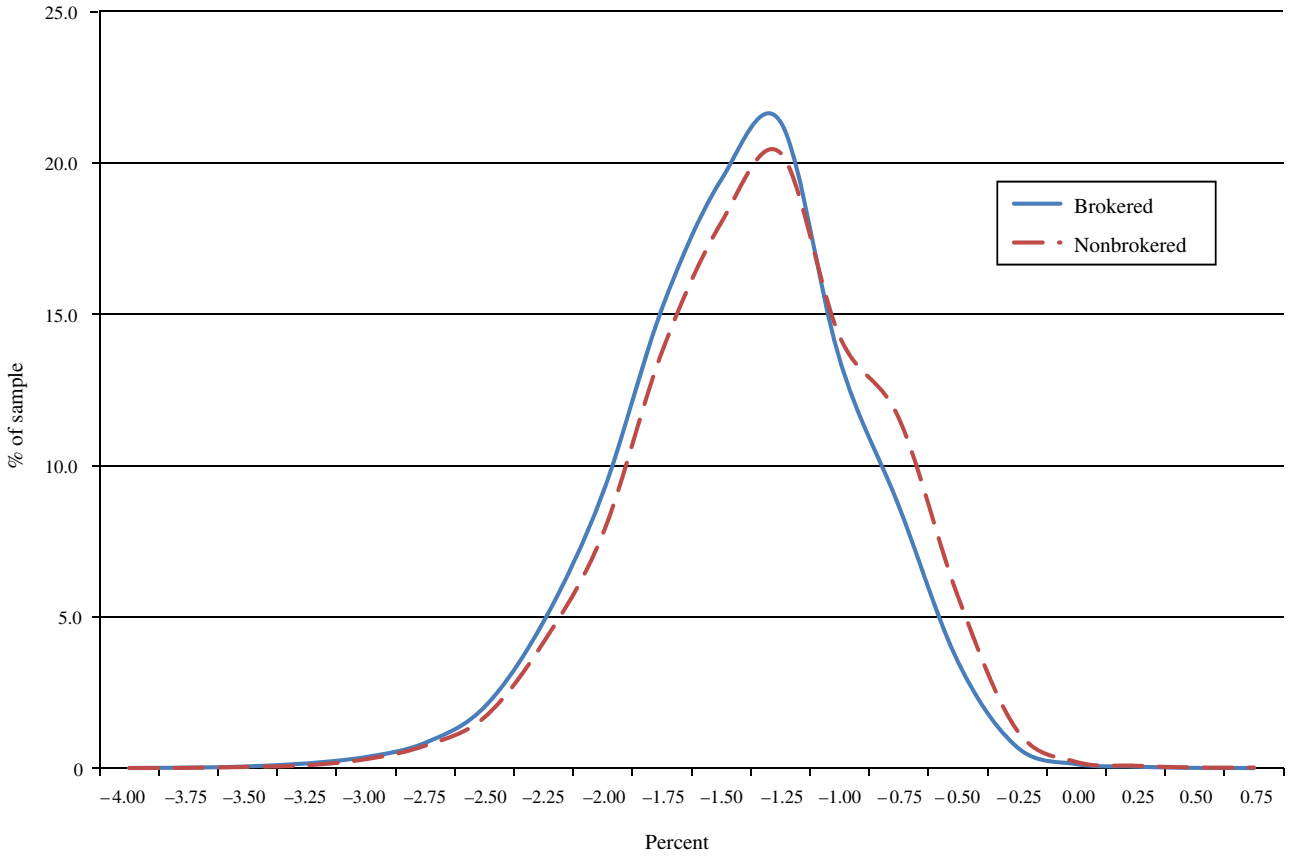
Figure 3 shows, brokers seem to focus disproportionately on a 50-basis-point-rate differential as the time to refinance. The distribution of Δ*rate* for brokered and nonbrokered refis is similar except for the bulge near 0.50%. Because of this and the other differences between brokered and nonbrokered refis, we run our baseline regressions to see whether errors of omission and commission are different for the two types of refis. We find that the use of a broker does not change the qualitative results (see the online appendix for details).

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 behavior 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 markets. Although all of these variables significantly affect refinancing decisions, they do not affect the significance or signs of our key coefficients (see the online appendix for details).

5. Conclusions

Choosing when to refinance a mortgage is one of the most important decisions a person can 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. Estimating the optimal refinancing rate using a simple closed-form solution for the optimal refinancing rate (Agarwal et al. 2012), we find evidence consistent with this: borrowers in our sample refinance at mortgage rates that we estimate are, on average, 60 basis points higher than the optimal rate for those borrowers, with 50% of borrowers missing by

Figure 3 **(Color online) 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 Nonbrokered Refis**



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 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.

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 et al. 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 implications as outlined in Campbell et al. (2011).

Supplemental Material

Supplemental material to this paper is available at https://doi.org/10.1287/mnsc.2015.2272.

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