

An Empirical Analysis of Information Asymmetry in Home Equity Lending*

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An Empirical Analysis of Information Asymmetry in Home Equity Lending

Abstract We analyze more than 74,000 home equity loans and lines of credit to study the role of information asymmetry. This credit market is characterized by borrowers who face a menu of contract options with varying collateral requirements and prices. Our results show that a less credit worthy applicant is more likely to select a credit contract that requires less collateral. Further analysis on the borrower's repayment behavior after controlling for observable risk attributes indicates that the lender faces adverse selection and moral hazard due to private information.

Keywords Asymmetric information • Adverse selection • Moral hazard • banking • Home equity lending

JEL Classification D1 • D8 • G21

1 Introduction

Adverse selection and moral hazard can occur in a credit market where participants have asymmetric information (Akerlof 1970). Consequently, the use of interest rates or collateral in the screening process can introduce adverse selection that reduces a lender's overall expected loan profitability (Stiglitz and Weiss 1981).¹ The use of collateral in the screening process is consistent with lenders sorting borrowers on observable risk characteristics. In contrast, lenders can also attempt to offset the impact of adverse selection by offering a menu of contracts containing combinations of interest rates and collateral levels that allow borrowers to self-select contracts that ex ante disclose their risk (Bester 1985). The use of a menu of contracts to uncover information is consistent with borrowers being sorted on private (unobservable) information.

A number of studies have followed Stiglitz and Weiss (1981) and Bester (1985) to examine the role that collateral plays in determining the borrower's selection of loan contracts. The Bester model predicts that high-risk borrowers are more likely than low-risk borrowers to choose contracts with higher interest rates and lower collateral requirements, thus eliminating the problems of adverse selection – the classic case of Stiglitz and Weiss's credit rationing. Chan and Thakor (1987) also develop a model in which a borrower's use of collateral could be a positive function of the borrower's credit quality. Furthermore, Igawa and Kanatas (1990) note that the use of collateral might introduce additional default risk through moral hazard if the collateral's future value can be affected by the borrower's use of the pledged asset. Their model of optimal contracts provides a framework that allows lenders and borrowers to minimize the impact of moral hazard,

which implies a positive relation between the borrower's credit quality and the collateral offered.²

We use unique proprietary data to study the role of information asymmetry in the home equity credit market where borrowers face a menu of contract options with varying collateral requirements and prices. An applicant self-selects a contract based on his or her own assessment of the property value and other private information. After the borrower self-selects the contract, the lender takes one of the following actions: (1) rejects the contract, (2) accepts the contract, or (3) suggests an alternative contract. To overcome the bias from using loans that are already originated, we follow a set of loan applications through a loan underwriting process and then through a period of post-origination performance. Using information from this dynamic contracting process, our study provides additional insights into the role of information asymmetry in a secured consumer credit market. Because we are able to observe a borrower's initial contract choice, we can test to see whether a borrower's contract choice discloses information about his or her risk level. Specifically, do riskier borrowers self-select a contract that requires less collateral? In addition, by following the borrower through his or her post-origination performance, we investigate, conditional on a borrower's initial contract choice and other risk observable characteristics, whether adverse selection and moral hazard are present in the home equity lending market.

¹ In this classic case, the lender's overall loan profitability declines because the quality of the average borrower declines as the interest rate or collateral increases since only higher risk borrowers are willing to pay higher interest rates or post greater collateral. As a result, the lenders ration credit.

² To test these theories, a number of studies examine the relation between borrower risk and the collateral pledged. The findings are mixed. Some studies report a positive relation (e.g., Berger and Udell 1990; Machauer and Weber 1998; John et al. 2003; Brick and Palia 2007; Godlewski and Weill 2011), while others find a negative relation (e.g., Degryse and Van Cayseele 2000; Jimenez and Saurina 2004; Agarwal and Hauswald 2010; Berger et al. 2011).

The empirical research that tests for the presence of adverse selection and moral hazard in credit markets often faces identification challenges, particularly in distinguishing between adverse selection and moral hazard. The traditional data sets on financial contracts and surveys only contain information about contracts that are already booked and in turn, cannot identify a borrower's contract choice ex ante. In more recent attempts, Dey and Dunn (2006) use the "Survey of Consumer Finance" (SCF) data to examine the role that collateral plays in distinguishing a borrower's risk level in a home equity line of credit and find that riskier borrowers are more likely to pledge lower amounts of collateral. Edelberg (2004) uses the SCF data on automobile and mortgage loan contracts to examine the relation between interest rates, collateral values, and loan performance. She finds strong evidence that ex post high-risk borrowers self-select contracts with lower collateral levels and higher interest rates, which suggests that adverse selection is present. At the same time, she finds that collateral is used to induce borrower effort, which suggests the presence of moral hazard. Karlan and Zinman (2009) find compelling evidence that supports the significant presence of adverse selection and moral hazard by using a field experiment that randomizes loan pricing at solicitation and loan pricing at origination. The authors conclude that between 6 and 17% of the defaults in their sample can be attributed to adverse selection and moral hazard, respectively. In a more recent paper, Adams et al. (2009) analyze the demand of subprime auto loan applicants and their subsequent repayment behavior. They cleverly disentangle adverse selection and moral hazard by incorporating the residual from the loan amount demand regression into the default regression, and estimate that about 8 and 16% of subprime auto defaults is due to adverse selection and moral hazard respectively.

Other empirical research investigating adverse selection problems in the consumer credit market focus on unsecured lending. One of this research's most influential papers is Ausubel (1991). Ausubel empirically shows the stickiness of credit card rates relative to the cost of funds and contends that the rates are sticky because cardholders are unable to switch to lower rate cards due to adverse selection problems arising from search and switching costs. Using preapproved credit card solicitations, Ausubel (1999) and Agarwal et al. (2010) find evidence of sorting by observable and unobservable information that supports the presence of adverse selection in credit card lending. Also supporting the view that adverse selection can result from high search costs, Calem and Mester (1995) use data from the 1989 SCF to show that households looking to borrow additional funds hold lower credit card debt. Furthermore, consistent with the impact of switching costs, Calem and Mester (1995) find that households holding larger credit card debt are more likely to be denied future credit and to experience repayment problems on existing credit.

Our paper is closely related to Adams et al. (2009) who investigate the importance of adverse selection and moral hazard in the consumer credit market. However, they analyze subprime auto loan applicants, a lower credit quality population. In this paper, we are able to provide additional evidence by focusing on the home equity market toward low-risk "prime" borrowers (population). Our study can be considered as a minimal test of the importance of adverse selection and moral hazard in the consumer credit market.

To preview our results, after controlling for borrower age, income, employment, and other observable attributes, we find that a borrower's choice of credit contract does disclose information about his or her risk level, which is consistent with the implications of Bester (1985). Specifically, we find that a less credit-worthy borrower is more likely to

self-select a contract that requires less collateral (and vice versa). However, after controlling for observable risk characteristics we find that the lender might still face adverse selection and moral hazard problems due to private information. That is, we find a significant and strong negative correlation between a borrower's contract choice to pledge collateral ex ante and the risk of default ex post. Our results indicate that a borrower choosing to pledge less than 10% of collateral is 7.76% more likely to default in comparison with a borrower choosing to pledge more than 20% collateral.³ Moreover, we disentangle adverse selection and moral hazard by incorporating the contract choice residual into the default regression. We estimate that about 3.98 and 3.78% of the increases in default probabilities are due to adverse selection and moral hazard, respectively.

The paper proceeds as follows. In Section 2, we describe the home equity lending process and discuss the data. In Section 3, we provide an outline of the empirical methods and present our results. We conclude with Section 4.

2 Home equity credit market and data

The market for home equity loans and home equity lines of credit represents a large segment of the consumer credit market. By the end of 2012, home equity lending increased to over \$770 billion.⁴ The home equity credit market presents an ideal framework in which to investigate the role of information asymmetry because home equity credit is secured by the borrower's home, and the borrower generally faces a menu of standardized contracts. For example, a typical home equity menu might offer a 15-year home equity line of credit

³ Given that the home equity menu of contracts is not a continuous risk-based pricing menu but necessarily offers a set of coarse interest rates and collateral requirements, the problems of information asymmetry might be reduced, but cannot be completely eliminated.

⁴ See Federal Reserve Statistical Release, Z.1 (2012).

with less than an 80% loan-to-value ratio (LTV) at interest rate r_1 ; a 15-year home equity loan with a first lien between an 80 and 90% LTV at interest rate r_2 ; or a 15-year home equity loan with second lien between a 90% and 100% LTV at interest rate r_3 , where $r_1 < r_2 < r_3$. In turn, a borrower's initial contract choice might disclose information about his or her expected tenure and risk.

Credit rationing in the classic Stiglitz and Weiss (1981) framework occurs when the observable risk characteristics of the borrower are well below the lender's acceptable underwriting standards.⁵ If the borrower's risk profile meets the lender's minimum underwriting criteria, then the lender accepts the initial contract and originates the loan or recommends an alternative contract for the borrower's consideration. Thus, after the borrower self-selects a contract, the lender takes one of the following actions: (1) rejects the contract (credit rationing), (2) accepts the contract, or (3) suggests an alternative contract.

Based on the above description of the origination process, a number of testable hypotheses arise concerning the presence of asymmetric information in the home equity lending market. First, evidence of borrower sorting on private information in the home equity lending market implies that we should observe differential responses to the lender's menu, with higher risk (lower-risk) borrowers selecting a loan contract having higher (lower) LTV ratios and higher (lower) interest rates (Bester 1985). Second, if borrowers that self-select higher (lower) LTV contracts have higher (lower) probabilities of default, then the lender could still face problems of information asymmetry due to private (unobservable) risk factors (Ausubel 1999).

⁵ Credit rationing is not from the entire market because other lenders might offer the borrower credit.

To empirically assess the role of asymmetric information in the home equity lending market, we collect an administrative data set of home equity contract originations from a large financial institution. The data set is similar to the one in Agarwal et al. (2011) that contains rich information about the borrower's credit quality, income, debts, age, occupation status, and the purpose for the loan. However, our data set only includes loan applications that were either accepted or rejected in the primary screening. Those loan applications going through the second screening are excluded due to the fact that the interactions between the borrowers and the lender played an important role in choosing their contacts.

Our sample contains 74,257 home equity loan applications between March and December of 2002. During this period, lenders offered a menu of standardized contracts for home equity credit. Consumers could choose to (1) increase an existing line of credit, (2) request a new line of credit, (3) request a new first-lien loan, or (4) request a new second-lien loan.⁶ For each product, borrowers could choose the amount of collateral to pledge: more than 20 cents per dollar loan (LTV of less than 80%), 10 to 20 cents per dollar loan (LTV of 80 to 90%), or zero to 10 cents per dollar loan (LTV of 90 to 100%). We are able to observe in our data set which of the 12 combinations of LTVs and product type contracts that the customer self-selects. In addition to observing the lender's response

⁶ Both first lien loans and second lien loans are secured obligations of the borrowers. However, in the event of a bankruptcy or liquidation, the assets used by the borrowers as security would first be provided to the first lien secured lender as repayment of the first lien loans. After satisfying the borrowers' obligations to the first lien secured lenders, any additional proceeds from the sale of the pledged assets would then be made available to the second lien lenders as repayment of the second lien loans. Usually, a borrower will take a second lien home equity loan either at the same time or after taking a traditional first lien mortgage loan. The specific rights of the first lien and second lien home equity loans are established in the credit agreements between the borrowers and each class of lenders.

to an applicant's contract choice, we also observe the borrowers' payment behaviors from origination to March 2005.

Table 1 presents the summary statistics for both accepted and rejected applications, respectively. Based on the information disclosed in the application, the lender rejected 12,006 applications (16.2%), and accepted 62,251 applications (83.8%). As expected, the credit quality of the applicants who were accepted is higher than the credit quality of those who were rejected. The average FICO score of applicants who were accepted is 737, while the average FICO score of the applicants who were rejected is 714. Furthermore, the rejected applicants averaged a shorter tenure at their current address (94 months), a lower annual income (\$82,058), a higher debt-to-income ratio (45%), and were more likely to be self-employed (12%) than applicants who were accepted (152 months tenure, \$121,974 annual income, 34% debt-to-income ratio, and 8% self-employment).

The borrower's LTV is based on the borrower's self-declared property value and loan amount request, while the lender's LTV is calculated using the property value from an independent appraisal and the lender-approved loan amount. Focusing on the LTV ratio for the set of applications that were rejected, we observe that the lender's LTV estimate averages 8 percentage points higher than the borrower's estimated LTV (82 versus 74%). This finding indicates that borrowers who were rejected tend to overvalue their homes relative to the lender's independent appraisal. In contrast, the difference between the lender's and borrower's LTV ratios is only slightly higher for the accepted applications (56 versus 54%).

3 Empirical methods and results

3.1 Credit contract choice

We begin by investigating the correlation between a borrower's credit quality and his or her initial contract choice. As outlined in Section 2, a borrower faces a menu of home equity contracts at the initial application stage. The borrower applies for a specific home equity contract based on his or her own valuation of the property and other private information regarding his or her credit risk, financing needs, and uncertain expectations for the outcome of the application. If the choice on the amount of collateral serves as a borrower-risk-level sorting mechanism during the application process, then we should observe a positive correlation between the borrower's credit quality and the choice of collateral.

To test whether borrowers with higher (lower) credit quality offer more (less) collateral, we categorize the home equity applications into three groups based on the borrower's choice of LTV. Table 2 presents the summary statistics of the borrowers' credit risk characteristics segmented by the borrowers' contract choices (LTV ratio less than 80%, LTV ratio between 80 and 90%, and LTV ratio greater than 90%) at the time of application. As expected, we observe that borrowers choosing contracts with higher LTVs are, on average, less credit worthy than borrowers choosing lower LTV contracts. For example, the average FICO score is 708 for borrowers who select the contract with a LTV ratio above 90%, and the score is 738 for borrowers that choose a LTV ratio less than 80%. The difference in FICO scores between these two groups is statistically significant. Given that the FICO score is an index constructed to evaluate an individual's relative risk of default conditional on his or her credit risk profile. A lower FICO score implies a higher

probability of a borrower defaulting on his or her outstanding debt in the next 12 to 24 months. These results suggest that the borrowers who choose the contract with the LTV ratio greater than 90% are more risky as compared to the borrowers who choose either the contract with LTV ratio less than 80% or the one between 80% and 90%.

Other risk characteristics also demonstrate significant differences among the three groups of borrowers. Relative to the borrowers who select contracts with the lowest LTV ratio, the borrowers who choose contracts with the highest LTV ratio are on average younger (41 years old versus 51 years old), have a shorter tenure at their current address (72 months versus 172 months), have a lower annual income (\$101,640 versus \$118,586), have a higher debt-to-income ratios (44% versus 34%), and have fewer years at their current job (8.15 years versus 9.82 years). The t-tests for the above differences are all highly significant. The results indicate that riskier borrowers are more likely to apply for a higher LTV home equity contract.⁷

3.2 Lender response to borrower's contract choice

We now turn to an analysis of the lender's underwriting decisions in response to a borrower's contract choice. After receiving the borrower's application, the lender screens the loan by using observable information to determine whether the application should be rejected, accepted, or subjected to additional screening for asymmetric information.

We model the outcome (O) of the lender's primary screening as a logit model:

$$\Pr(O_i = l) = \frac{e^{(\alpha_j + \beta_j X_i + \delta_j W_i + \gamma_j LTV_i)}}{\sum_{k=1}^3 e^{(\alpha_k + \beta_k X_i + \delta_k W_i + \gamma_k LTV_i)}} \quad (1)$$

where $O_i=\{0,1\}$ corresponds to the lender's acceptance or rejection of the application respectively. Given that the lender's underwriting model uses the lender's independent appraised value of the property, the LTV_i is the lender's LTV category, while X_i and W_i represent vectors of the control variables and the borrower's credit score respectively. We include X in all of the information that the lender collects on a loan application.

Table 3 provides the logit estimation results for the lender's underwriting decision. Using loans that are accepted as the base case, we estimate the likelihood that the lender will reject an applicant conditional on the lender's LTV estimate, borrower risk characteristics, loan characteristics, and other control variables. Turning first to the impact of the lender's estimated LTV ratio, the significant and positive coefficients indicate that applicants in the 80 to 90% LTV category or applicants in the greater than 90% LTV category are more likely to be rejected than outright accepted. The reported marginal effects suggest that an application with the highest lender-estimated LTV in comparison to the lowest LTV estimate is 18.4% more likely to be rejected than accepted. Similarly, an application with the mid-range lender-estimated LTV ratio in comparison to the lowest LTV is 8.7% more likely to be rejected than accepted outright. Hence, the lender is more likely to ration applicants with both 80 to 90% LTV ratios and greater than 90% LTV ratios.

Looking at the other risk characteristics, we find that each additional percentage point increase in the debt-to-income ratio increases the probability that the lender will reject a loan by 1.8%. The borrowers who are rate refinancing are 2.6% less likely to be denied credit. The borrowers who select a first-lien product are 12.2% less likely to be

⁷ To verify the robustness of the preceding results, we follow Agarwal et al. (2011) and estimate a multinomial logit model on an applicant's choice of a LTV contract. The results are fully consistent with the

rejected. Finally, borrowers who own a condo are 6.5% more likely to be rejected, while borrowers who own a second home are 6.1% more likely to be rationed.

The results from this subsection are consistent with standard underwriting protocol. The factors that are associated with higher default risks (e.g., lower credit quality, higher LTV, and higher debt-to-income) are associated with a higher probability of being rationed.

3.3 Repayment behavior ex post—Testing for information asymmetry

In this subsection, we assess the relation between the choice of a LTV contract and the repayment behavior, both of which are conditional on observable borrower and loan attributes. Following standard methods in credit research, we estimate a Cox proportional hazard model of the loan performance for the 62,251 borrowers whose applications are accepted. We follow the empirical method that is outlined in Agarwal et al. (2006) and estimate the model based on the maximum likelihood estimation approach with grouped duration data developed by Han and Hausman (1990) and McCall (1996).

In the model, we add a set of dummy variables denoting a borrower's choice of a LTV contract to test for information asymmetry. The presence of borrower adverse selection due to unobservable information is consistent with the borrowers self-selecting contracts with higher LTV ratios that have higher risk of default (see Ausubel 1999). Meanwhile, a positive relation between the borrower's LTV choice and default risk is also expected if moral hazard is present.

findings in Table 2.

We also add as control variables the information collected from the loan application that indicates the borrower's employment status (e.g., employed, self-employed, retired, or homemaker), number of years employed, the borrower's income at the time of application, the property type (single-family detached or condo), the property's status as a primary residence or second home, the tenure in the property, the use of the funds (e.g., refinancing, home improvement, or debt consolidation), the current existence of a first mortgage on the property, and the borrower's use of an "auto-draft" feature to automatically make the monthly payment. We also include a series of dummy variables that denote the borrower's location (state) to control for unobserved state-specific factors. The dummy variables correspond to the calendar quarters (Q3:99–Q1:02) at origination can capture the unobserved shifts over time in economic conditions or borrower characteristics that might impact the propensity to default.

Table 4 presents the estimated coefficients and marginal effects for the Cox proportional hazard model of loan performance. The borrower's credit quality (as measured by the FICO score) is negatively correlated to the risk of default (borrowers with lower credit quality are more likely to default). In addition, default risk rises for the borrowers with higher debt-to-income ratios. The borrowers without a first mortgage and those using the home equity credit for rate refinancing or remodeling (investment in the home) are less likely to default. The risk of default declines as a borrower's tenure in the house increases. Interestingly, borrowers who choose to automatically pay their monthly mortgage directly from their checking account, relative to those borrowers who pay by invoice, are 7.04% less likely to default. The borrowers who select a home equity loan are 8.06% more likely to default than the borrowers who select a home equity line. Moreover,

the borrowers who choose a home equity credit with a first-lien position are 3.14% less likely to default than borrowers who originate a loan or line with a second lien.⁸

We find a positive and statistically significant correlation between a borrower's LTV choice and risk of defaulting after controlling for all of the observable risk characteristics captured on the loan application. Relative to the borrowers pledging with a LTV ratio less than 80%, those pledging with a LTV ratio between 80 and 90% are 3.73% more likely to default, while those pledging a LTV ratio greater than 90% are 7.76% more likely to default.

In sum, borrowers who self-select into a higher risk contract have a higher risk of default. The positive and significant relation between the borrower's choice of contract and the loan's performance suggests that the lender might face problems of adverse selection and moral hazard during its origination.⁹

While we believe the results are consistent with the presence of information asymmetry in the home equity lending, an alternative possibility could account for the relation between contract choice and performance, a mechanical process could explain our finding. That is, default is linked to the borrower's debt level at origination. Even in the absence of adverse selection or moral hazard a borrower who obtains a larger loan, relative to the home's equity, should have a higher default probability. Similarly, for a given loan, a borrower who has greater home equity should have a lower default probability. As

⁸ A borrower with a second lien also has an obligation towards the primary mortgage. On average, their total debt burden will be higher; this will impact the probability of the default. Moreover, the average interest rate for the second-lien products is 30 basis points higher than the first-lien products. This will negatively impact the borrower's debt service burden resulting in higher default rates.

⁹ Agarwal et al. (2006) note that the default and prepayment behavior of loans and lines are different. Thus, we also estimated the Cox proportional hazard model for loans and lines independently. While the results confirm that loans have a higher probability of default and lines have a higher probability of prepayment, estimating the models separately does not impact the findings for the dummy variables of information asymmetry.

compared to a borrower with LTV of more than 90%, the borrower with a LTV less than 80% can borrow more in the future and is also more likely to receive additional loans from the same bank or another lender if both are hit by a negative income shock. As a result, it is natural that the borrower with a LTV of less than 80% is less likely to default, because he or she can get additional credit from other sources.

To address this potential issue, we introduce a number of variables to capture the post-application changes in the borrower's liquidity and financial positions that are not known to the bank at the time of application.

To control for the impact of changing property values on the probability of default, we construct time-varying loan-to-value ratios (CLTV) by using the quarterly OFHEO MSA level repeat sales indices to estimate the changes in house prices. We also include the square of the CLTV to control for any nonlinearity. A dummy variable for a positive quarterly change in the loan-to-value ratio (CLTV_Diff_Dummy) is added to capture the changes in default option values. We capture changes in the borrower's credit constraints via the time-varying borrower credit score (FICO) and add the square of the FICO to capture any nonlinearity. Local economic conditions might also impact the decisions to terminate mortgage (see Hurst and Stafford 2004). Thus, we use the current county unemployment rate (UnempRate) as a proxy for local economic conditions.

We also add a number of variables to control for account seasoning (AGE of account, and AGE-square). The $AGE_{i,t}$ is the number of months since the origination at time t , and, as Gross and Souleles (2002) point out, allows for seasoning. That is, AGE accounts for changes in the default propensity as loans mature.

Finally, with respect to the role of collateral, we also add the percentage difference between the borrower's initial house value assessment and the lender's independently appraised value at origination (HouseVal_Diff). Agarwal (2007) finds that borrowers who underestimate their house value are more likely to refinance without cash and prepay their loans while borrowers who overestimate their house value are more likely to cash out and default on their loans. Thus, the percentage difference in valuation estimates (HouseVal_Diff) provides a rough proxy for the borrower's risk aversion.

The second column of Table 4 reports the richest specification that includes the full set of observable characteristics at origination and post-origination time-varying default related variables. We still find a positive and statistically significant correlation between a borrower's LTV choice and the risk of default. Relative to the borrowers with a LTV ratio less than 80%, those with LTV ratio between 80 and 90% are 2.22% more likely to default, while those with LTV ratio greater than 90% LTV are 5.57% more likely to default. With the results, we believe the positive and significant relation between the borrower's choice of contract and loan performance captures the effect of adverse selection and moral hazard during loan origination.

3.4 Adverse selection versus moral hazard

The findings in subsection 3.3 are consistent with the presence of both adverse selection as well as moral hazard. The presence of the borrowers' adverse selection due to unobservable information is consistent with the borrowers' self-selecting contracts with higher LTV ratios that have a higher risk of default. A positive relation between the probability of default and contract choices could also arise from moral hazard. The borrowers with less collateral might make less of an effort to produce the income necessary

to pay back the loan, because they lose less in default. Moreover, these borrowers also pay higher interest rates. This higher interest reduces their payoffs in the good states of the world and hence should reduce effort. A more challenging issue is to distinguish between adverse selection and moral hazard. Karlan and Zinman (2009) are able to distinguish between the two phenomena only because of a particular design of their experiment directly aimed at this distinction. Unfortunately, the data we have does not allow us to follow their approach. Instead, we follow the empirical method in Adams et al. (2009) that uses a two-stage estimation approach in which we can estimate the default model using the residual from a model on the choice of the credit contract by the borrower as an explanatory variable.

Specifically, we start by specifying an empirical Tobit model of the borrower's LTV decision as

$$LTV_i = \beta X_i + \varepsilon_i \quad (2)$$

where LTV_i is the borrower's LTV choice, and X_i represents a vector of control variables. The control variables are information collected from the loan application and include the borrower's FICO score, employment status, number of years employed, age and income at the time of application, the property type, the property's status as the primary residence or second home, the tenure in the property, the use of the funds, and the current existence of a first mortgage on the property. With the detailed information collected from the loan application, we can control for most factors that affect the borrower's contract choice.

However, we recognize that despite our rich controls in the model, the borrower might have private information at the time of choosing the contract that affects his or her later loan performance. So we can use the estimated residual from the contract choice

model to measure the borrower's private risk type that is unobservable at origination. Thus, if the lender faces adverse selection problems due to unobservable risk types, we should find the residual to have a significant impact on borrower' default behavior.

In the second stage, we add the residual in estimating the Cox proportional hazard model of the loan performance as in subsection 3.3. This specification isolates the effect of moral hazard in the coefficient of the contract choices and also contains the test for adverse selection arising from asymmetric information. Recall that the estimated coefficient on the borrower LTV choice in Table 4 pools both the adverse selection and moral hazard effects. Under the current specification, the effect of adverse selection is captured by the residual variable; the remaining variation in the borrower's LTV choice is due entirely to moral hazard.

Table 5 presents our estimates from the Tobit model of the borrower's LTV decision; these are consistent with the findings in subsection 3.1. Less credit-worthy borrowers are more likely to choose higher LTV contracts. The borrowers with higher debt-to-income ratios are more likely to apply for higher LTV contracts. The younger borrowers are also more likely to choose higher LTV contracts. In addition, a borrower having a second home is less likely to apply for a higher LTV contract.

Table 6 presents the results from the default model that adds the estimated contract choice residual as an explanatory variable to control for adverse selection. We can interpret the coefficient on contract choice as the effect of moral hazard. Like in Table 4, we report two specifications: one with only observable characteristics at origination and another one adding post-origination time-varying default related variables as controls. The results from both specifications all display a positive and statistically significant correlation between a

borrower's LTV choice and the risk of defaulting. This correlation indicates the presence of moral hazard. For example, the first specification shows that, relative to the borrowers with the lowest LTV ratio, those with the mid-range LTV ratio are 1.77% more likely to default due to moral hazard, while those with the highest LTV ratio are 3.78% more likely to default due to moral hazard. Furthermore, we know from Table 4 that adverse selection and moral hazard jointly increase default probabilities by 3.73% for the borrowers with the mid-range LTV ratio and 7.76% for those with the highest LTV ratio respectively. This finding implies that adverse selection contributes 2.01% increases in the probability of default for borrowers with the mid-range LTV ratio and 3.98 for those with the highest LTV ratio respectively. Additionally, a positive and significant coefficient on the contract choice residual supports the presence of adverse selection.

4 Conclusions

We use a unique proprietary data to study the role of information asymmetry in the home equity credit market where more than 74,000 applicants face a menu of contract options with varying prices. Our empirical analysis suggests that a borrower's choice of credit contract reveals information about his risk level. Specifically, we find that less a credit-worthy borrower is more likely to select a contract that requires him to pledge less collateral. With the information about the riskiness of the borrowers from their self-select on observable information, the lender is more likely to reject applicants who have chosen higher LTV contracts.

We then test for information asymmetry by estimating the likelihood of a borrower defaulting on his home equity debt as a function of LTV contract type, while controlling

for information on a borrower's risk attributes observed by the lender at the time the application was accepted. We find, after controlling for observable risk characteristics, a positive and statistically significant correlation between a borrower's choice of collateral pledged ex ante and his risk of defaulting ex post. The significant relation identified among the variables denoting the borrower contract choice ex ante and loan performance ex post suggest the presence of adverse selection and moral hazard on unobservable factors, consistent with Ausubel's (1999) findings in the credit card market.

Moreover, we follow the empirical methodology in Adams et al. (2009) in which we estimate the default model using the borrower contract choice residual as a control for adverse section, we are able to show that both adverse selection and moral hazard are responsible for the positive relation between a borrower's choice of collateral pledged ex ante and his risk of defaulting ex post.

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Table 1 Descriptive statistics of home equity credit applications. This table reports the sample's descriptive statistics of home equity loan and line applications segmented by the lender's underwriting decision: accept or deny. The loan amount requested is the total credit line or loan amount recorded on the borrower's application. Borrower LTV is the loan-to-value ratio calculated using the applicant's requested loan amount and the applicant's self-reported property value. Lender LTV is the loan-to-value ratio calculated using the approved loan amount and the property value determined by the lender's independent appraisal. Annual percentage rate (APR) is the effective interest rate on the offered loan. FICO is the borrower's credit score at the time of application. Reasons for the loan are the borrower's reported use of funds. Months at address is the total number of months the borrower reports he or she has resided at the current address. Income is the borrower's reported annual income. Debt-to-income is the borrower's total debt payment divided by reported income. Employment information indicates whether the borrower is employed, self-employed, retired, or homemaker, as well as the number of years with his or her current employer.

	(1)		(2)		(3)	
	Total Applications		Accepted Applications		Rejected Applications	
	MEAN	STD	MEAN	STD	MEAN	STD
Loan Amount Requested (\$)	67,726	50,270	67,619	50,288	68,283	54,677
Borrower LTV (%)	57	23	54	23	74	24
Lender LTV (%)	60	24	56	23	82	30
Loan Amount Approved (\$)	-	-	68,870	52,158	-	-
Annual Percentage Rate (%)	-	-	4.68	1.22	-	-
FICO	733	51	737	51	714	54
Reported Reason for Loan :						
Refinancing (%)	40	-	39	-	43	-
Consumption (%)	35	-	36	-	31	-
Home Improvement (%)	25	-	25	-	25	-
No First Mortgage (%)	25	-	26	-	19	-
Months at Address	142	129	152	134	94	107
Income (\$)	115,521	205,462	121,974	213,853	82,058	170,174
Debt-to-Income (%)	36	19	34	19	45	21
Employment Information:						
Employed (%)	81	-	80	-	82	-
Self-Employed (%)	9	-	8	-	12	-
Retired (%)	9	-	10	-	5	-
Homemaker (%)	1	-	1	-	1	-
Years on the Job	9.52	9.52	9.79	9.95	8.12	8.28
Borrower Age	49	13	50	12	47	13
Number of Observations	74,257		62,251		12,006	

Table 2 LTV contract choices by borrowers. The table reports the summary statistics of home equity credit applications segmented by an applicant's loan-to-value ratio (LTV) contract choice: a LTV ratio less than 80%, a LTV ratio between 80% and 90%, and a LTV ratio greater than 90%. The data set includes 74,257 home equity credit applications

Variable Name	(1)	(2)	(3)	T-test for Differences		
	LTV <80	LTV 80-90	LTV >90	(1)-(2)	(1)-(3)	(2)-(3)
Loan Amount Requested (\$)	69,035 (50,412)	68,659 (52,516)	55,378 (38,071)		***	***
Borrower LTV (%)	48 (21)	85 (13)	95 (9)	***	***	***
FICO	738 (46)	722 (51)	708 (43)	***	***	***
Reported Reason for Loan:						
Refinancing (%)	39	42	44			
Home Improvement (%)	25	26	28			
Consumption (%)	36	32	28			
Months at Address	159 (116)	79 (92)	72 (80)	***	***	***
Income (\$)	118,586 (190,308)	104,878 (131,987)	101,640 (102,084)	***	***	*
Debt-to-Income (%)	34 (18)	42 (17)	44 (17)	***	***	*
Employment Information :						
Employed (%)	78	90	91			
Self-Employed	10	6	6			
Retired	11	3	2			
Homemaker	1	1	1			
Years on the Job	9.82 (9.54)	8.55 (7.52)	8.15 (6.81)	***	***	**
Borrower Age	51 (14)	42 (11)	42 (12)	***	***	
Number of Observations	59283	8083	6891			

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

Table 3 Lender's underwriting decision. This table reports the estimated coefficients and marginal effects of the logit model of the lender's initial underwriting decision. The base case is loans that were accepted. Lender LTV 80-90 is a dummy variable indicating loans with actual LTV ratios between 80 and 90%. Lender LTV 90+ is a dummy variable indicating loans with actual loan-to-value ratio (LTV) ratios greater than 90%. The data set includes 74,257 home equity credit applications.

Independent variables	Application Rejected		
	Coeff. Value	Std. Error	p-value
Intercept	-0.020	1.665	0.990
<i>Borrower Characteristics</i>			
FICO	-0.008	0.002	<.0001
FICO ²	-3.0E-04	6.0E-05	0.002
Log (Income)	-0.018	0.002	<.0001
Log (House tenure)	-0.067	0.011	<.0001
Debt-to-Income	0.005	0.001	<.0001
<i>Contract Characteristics</i>			
Lender LTV 80-90	1.652	0.033	<.0001
Lender LTV 90+	3.921	0.041	<.0001
First-Lien Dummy	-3.429	0.146	<.0001
Home Equity Loan Dummy	0.959	0.031	<.0001
Home Improvement	-0.028	0.033	0.390
Refinancing	-0.174	0.030	<.0001
No First Mortgage	-0.367	0.038	<.0001
Second Home	1.377	0.061	<.0001
Condo	1.305	0.041	<.0001
<i>Employment Control Variables</i>			
Log (Years on the Job)	-0.060	0.013	<.0001
Self-Employed	0.733	0.039	<.0001
Retired	-0.115	0.187	0.541
Homemaker	-0.216	0.078	0.005
<i>Location Control Variables</i>			
CT State Dummy	-0.357	0.048	<.0001
ME State Dummy	-0.737	0.083	<.0001
NH State Dummy	-0.323	0.079	<.0001
NJ State Dummy	-0.089	0.033	0.007
NY State Dummy	-0.153	0.037	<.0001
PA State Dummy	-0.115	0.060	0.057
RI State Dummy	-0.306	0.075	<.0001
Pseudo R-square	11.34%		
Number of Observations (accepted/rejected)	62,251 / 12006		

Table 4 Test of information asymmetry. This table reports the Cox proportional hazard model of loan default in order to test for adverse selection and moral hazard in the set of 62,251 applicants who were accepted. The base case is loans that remain current as of the end of the observation period (March 2005).

	(1)				(2)			
	Coeff. Value	Std. Error	p-value	Marginal Effects	Coeff. Value	Std. Error	p-value	Marginal Effects
Intercept	-11.562	1.445	<.0001		-9.075	1.173	<.0001	
<i>Borrower Characteristics</i>								
FICO	-0.181	0.014	<.0001	-0.46%	-0.182	0.012	<.0001	-0.49%
FICO ²	1.0E-04	10E-06	<.0001	0.00%	1.1E-04	9.1E-06	<.0001	0.00%
Log (Income)	-0.439	0.093	<.0001	-9.12%	-0.377	0.082	<.0001	-9.49%
Log (House tenure)	-0.238	0.031	<.0001	11.05%	-0.213	0.031	<.0001	-9.44%
Debt-to-Income	0.031	0.003	<.0001	3.09%	0.026	0.003	<.0001	2.06%
<i>Contract Characteristics</i>								
Bank LTV 80-90	0.340	0.139	0.005	3.73%	0.354	0.125	0.005	2.22%
Bank LTV 90+	1.508	0.227	<.0001	7.76%	1.291	0.180	<.0001	5.57%
Home Equity Loan Dummy	2.380	0.209	<.0001	8.06%	1.929	0.192	<.0001	5.38%
First-Lien Dummy	-0.640	0.091	<.0001	-3.14%	-0.653	0.090	<.0001	-2.26%
Refinancing	-0.503	0.116	<.0001	-6.15%	-0.521	0.110	<.0001	-3.70%
Home Improvement	-0.721	0.120	<.0001	-3.89%	-0.681	0.115	<.0001	-3.36%
No First Mortgage	-1.195	0.132	<.0001	-8.71%	-1.133	0.137	<.0001	-6.79%
Second Home	3.486	0.152	<.0001	2.20%	3.140	0.150	<.0001	2.08%
Condo	-2.700	0.425	<.0001	-1.81%	-2.251	0.345	<.0001	-1.26%
Auto Pay	-0.359	0.110	0.004	-7.04%	-0.360	0.099	0.000	-4.18%
<i>Time-varying Option Variables</i>								
CLTV					0.188	0.368	<.0001	3.98%
CLTV ²					1.288	0.384	<.0001	8.91%
CLTV_Diff_Dummy					1.012	0.218	<.0001	2.98%
HouseVal_Diff					0.345	0.074	<.0001	2.26%
Account Age					0.047	0.019	0.013	1.07%
Account Age ²					-4.4E-04	9.1E-05	<.0001	-2.55%
<i>Employment Control Variables</i>								
Log (Years on the Job)	-0.349	0.044	<.0001	-5.32%	-0.341	0.047	<.0001	-4.03%
Self-Employed	0.605	0.106	<.0001	0.22%	0.630	0.094	<.0001	0.19%
Retired	1.421	0.229	<.0001	0.51%	1.279	0.196	<.0001	0.32%
Homemaker	-1.065	1.357	0.421	-0.99%	-0.928	1.153	0.421	-0.65%
<i>Location and Economic Control Variables</i>								
Unemployment Rate					0.358	0.023	<.0001	1.62%
CT State Dummy	-1.606	0.252	<.0001	-0.11%	-1.465	0.249	<.0001	-0.07%
ME State Dummy	-2.350	1.212	0.077	-0.35%	-1.974	1.114	0.076	-0.30%
NH State Dummy	0.341	0.123	<.0001	0.68%	0.348	0.109	<.0001	0.47%

NJ State Dummy	-1.474	0.241	<.0001	-0.02%	-1.203	0.202	<.0001	-0.02%
NY State Dummy	0.227	0.126	0.029	0.03%	0.235	0.105	0.025	0.03%
PA State Dummy	1.066	0.123	<.0001	0.15%	1.035	0.116	<.0001	0.13%
RI State Dummy	-1.587	0.574	0.001	-0.22%	-1.593	0.473	0.001	-0.16%
Unobserved Heterogeneity								
Factors								
Loc1	1.596	0.500	<.0001		1.479	0.489	<.0001	
Loc2	1.660	0.613	<.0001		1.698	0.572	<.0001	
Mass2	0.488	0.143	<.0001		0.489	0.128	<.0001	
Time Quarter Dummies	Yes				Yes			
Pseudo R-square	8.93%				9.03%			
Number of Accts/Defaults	62,251	702						

Table 5 LTV contract choice by borrower. This table reports the estimates from the Tobit model of the borrower's loan-to-value ratio (LTV) contract choice.

Borrower LTV			
Independent variables	Coefficient	Std. Error	p-value
Intercept	-0.472	0.040	<.0001
<i>Borrower Characteristics</i>			
FICO	0.028	0.004	<.0001
FICO ²	-2.0E-05	0.0E+00	<.0001
Log (Income)	-0.022	0.021	0.187
Log (Borrower Age)	-1.185	0.060	<.0001
Log (House tenure)	-0.233	0.006	<.0001
Debt-to-Income	0.004	0.001	<.0001
<i>Contract Characteristics</i>			
First-Lien Dummy	-0.115	0.092	0.101
Home Equity Loan Dummy	0.069	0.030	0.008
Refinancing	0.055	0.027	<.0001
Home Improvement	0.002	0.028	0.618
No First Mortgage	-0.843	0.037	<.0001
Second Home	-0.825	0.086	<.0001
Condo	-0.039	0.044	0.340
<i>Employment Control Variables</i>			
Log (Years on the Job)	-0.031	0.008	<.0001
Self-Employed	-0.208	0.034	<.0001
Retired	0.101	0.090	0.144
Homemaker	-0.210	0.135	0.052
<i>Location Control Variables</i>			
CT State Dummy	0.234	0.035	<.0001
ME State Dummy	0.661	0.048	<.0001
NH State Dummy	0.355	0.055	<.0001
NJ State Dummy	-3.5E-04	0.019	0.664
NY State Dummy	0.025	0.032	0.286
PA State Dummy	0.496	0.046	<.0001
RI State Dummy	0.243	0.051	<.0001
Pseudo R-square	9.10%		
Number of Observations	74259		

Table 6 Test of adverse selection and moral hazard. This table reports the results from the Cox proportional hazard model of loan default that includes the estimated contract choice residual as an explanatory variable controlling for adverse selection. The base case is loans that remain current as of the end of the observation period (March 2005).

Independent variables	(1)				(2)			
	Coeff. Value	Std. Error	p-value	Marginal Effects	Coeff. Value	Std. Error	p-value	Marginal Effects
Intercept	-9.598	1.322	<.0001		-8.879	1.157	<.0001	
<i>Borrower Characteristics</i>								
FICO	-0.171	0.013	<.0001	-0.58%	-0.180	0.012	<.0001	-0.47%
FICO ²	1.0E-04	10E-06	<.0001	0.00%	1.1E-04	1.0E-05	<.0001	0.00%
Log (Income)	-0.466	0.089	<.0001	13.82%	-0.376	0.078	<.0001	-9.14%
Log (House tenure)	-0.195	0.036	<.0001	10.73%	-0.207	0.031	<.0001	-9.23%
Debt-to-Income	0.025	0.003	<.0001	2.50%	0.025	0.003	<.0001	2.00%
<i>Contract Characteristics</i>								
Bank LTV 80-90	0.248	0.126	0.003	1.77%	0.236	0.119	0.002	1.14%
Bank LTV 90+	0.682	0.209	<.0001	3.78%	0.648	0.174	<.0001	2.52%
Borrower LTV Residual	0.768	0.034	<.0001	14.33%	0.733	0.030	<.0001	8.89%
Home Equity Loan Dummy	1.792	0.220	<.0001	8.28%	1.834	0.192	<.0001	5.12%
First-Lien Dummy	-0.615	0.113	<.0001	-2.97%	-0.628	0.089	<.0001	-2.21%
Refinancing	-0.507	0.100	<.0001	-4.47%	-0.504	0.105	<.0001	-3.53%
Home Improvement	-0.665	0.109	<.0001	-4.15%	-0.664	0.112	<.0001	-3.30%
No First Mortgage	-1.191	0.144	<.0001	10.57%	-1.100	0.135	<.0001	-6.66%
Second Home	3.363	0.166	<.0001	3.34%	3.009	0.147	<.0001	2.05%
Condo	-2.600	0.336	<.0001	-2.07%	-2.231	0.343	<.0001	-1.26%
Auto Pay	-0.407	0.113	0.0003	-4.72%	-0.354	0.096	0.000	-4.00%
<i>Time-varying Option Variables</i>								
CLTV					0.188	0.359	<.0001	3.97%
CLTV ²					1.247	0.365	<.0001	8.62%
CLTV_Diff_Dummy					0.962	0.217	<.0001	2.96%
HouseVal_Diff					0.339	0.071	<.0001	2.23%
Account Age					0.045	0.018	0.013	1.03%
Account Age ²					-4.3E-04	9.0E-05	<.0001	-2.43%
<i>Employment Control Variables</i>								
Log (Years on the Job)	-0.376	0.047	<.0001	-3.77%	-0.338	0.045	<.0001	-3.91%
Self-Employed	0.583	0.083	<.0001	0.31%	0.605	0.090	<.0001	0.19%
Retired	1.457	0.247	<.0001	0.49%	1.275	0.196	<.0001	0.32%
Homemaker	-0.972	1.371	0.405	-1.08%	-0.904	1.133	0.409	-0.63%

Location and Economic

Control Variables

Unemployment Rate					0.349	0.023	<.0001	1.62%
CT State Dummy	-1.505	0.263	<.0001	-0.09%	-1.456	0.239	<.0001	-0.07%
ME State Dummy	-1.954	1.233	0.075	-0.41%	-1.970	1.106	0.075	-0.29%
NH State Dummy	0.390	0.124	<.0001	0.62%	0.335	0.109	<.0001	0.46%
NJ State Dummy	-1.267	0.201	<.0001	-0.03%	-1.181	0.200	<.0001	-0.02%
NY State Dummy	0.256	0.118	0.025	0.03%	0.224	0.101	0.024	0.03%
PA State Dummy	1.161	0.117	<.0001	0.16%	1.008	0.112	<.0001	0.12%
RI State Dummy	-1.810	0.463	0.001	-0.19%	-1.518	0.464	0.001	-0.15%
Unobserved Heterogeneity								
Factors								
Loc1	1.745	0.524	<.0001		1.418	0.479	<.0001	
Loc2	1.869	0.551	<.0001		1.626	0.565	<.0001	
Mass2	0.524	0.120	<.0001		0.466	0.128	<.0001	
Time Quarter Dummies	Yes				Yes			
Pseudo R-square	7.47%				7.81%			
Number of Accts/Defaults	62,251	702						