INFORMATION ACQUISITION IN COMPETITIVE MORTGAGE MARKETS*

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Abstract

In November 2008, the U.S. Department of Housing and Urban Development adopted revised rules requiring lenders to commit to the terms specified in a Good Faith Estimate, with mandatory compliance beginning in January 2010. This paper examines how price commitments impact information acquisition in the context of a competitive mortgage (or product/labor) market. Contracts are incomplete because the amount of information firms acquire about applicants during the underwriting process cannot be observed. We find that firms search for too much information in equilibrium. If price discrimination is prohibited, then members of high-risk groups suffer disproportionately high rejection rates. If rejected applicants remain in the market, then the resulting adverse selection can be so severe that all parties would be better off if no information was collected.

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1 Introduction

The recent sharp rise in U.S. mortgage default rates led to the most severe financial crisis since the Great Depression. The crisis was preceded by a historic increase in mortgage credit to *nonprime*[1] borrowers, among whom mortgage defaults have been particularly concentrated. In terms of total dollars, nonprime mortgages represented 32 percent of all mortgage originations in 2005, more than triple their 10 percent share only two years earlier (Inside Mortgage Finance, 2008). The share of nonprime mortgages that were seriously delinquent in September 2008 was more than quadruple that in mid-2005 (Mayer et al., 2009). A variety of explanations for the extraordinary growth in nonprime lending have been proffered; including improving economic fundamentals such as productivity and income gains, expansionary mortgage credit policies, predatory lending, and lax lending standards associated with securitization. A leading explanation is that lending standards dramatically weakened after 2004, where over time, lenders extended loans to increasingly risky borrowers (Mayer et al., 2009; Mian and Sufi, 2009, 2010; Demyanyk and Hemert, 2010; Keys et al., 2010).

The underwriting process is used to assess a borrower's risk profile to determine if they are qualified for a proposed loan. The borrower's employment, credit report and credit score, income, debt-to-income ratio, and funds on deposit for the down payment and closing costs need all be determined and verified. An appraisal will be ordered to assess the property's current value by using recent comparable sales and overall price trends; and is then used to determine the borrower's loan-to-value ratio. Lenders may also examine borrowers' past rent and utility payments and banking habits (e.g., looking for cases where direct deposits have stopped or large transactions took place).

During the nonprime mortgage boom the underwriting process was often perfunctory. Much of

[1] "Nonprime" borrowers are often further classified into "subprime" and "near-prime."

the information required to determine a borrower's risk profile was either uncollected or unexamined. Stated income loans, also known as 'liar loans', which require little or no evidence verifying claimed income, soared from $30 billion in 2001 to $276 billion in 2006, representing 46 percent of all subprime mortgages in that year.[2] Many unqualified borrowers were easily able to gain access to large amounts of credit.

To target the issues pertaining to poor underwriting standards, two approaches have been employed by regulators. One approach directly targets standards affecting mortgages backed or purchased by federal entities. To that end, underwriting guidelines provided by institutions such as Fannie Mae, Freddie Mac, and the Federal Housing Administration (FHA) have been tightened.[3] The second approach is focused on providing consumers with better information about the terms of mortgage loans. Recently, the U.S. Department of Housing and Urban Development (HUD), which enforces rules governing the Real Estate Settlement Procedures Act (RESPA)[4], revised some key contractual documents that govern the mortgage shopping and lending processes.

On November 8, 2007, HUD proposed revised RESPA rules to the government's Office of Management and Budget (OMB). These revisions were designed to address, among others, issues of misinformation and predatory lending. Finalized new rules were adopted on November 17, 2008, with mandatory compliance beginning January 1, 2010.[5] The new rules include a standardized Good Faith Estimate form (GFE) that requires lenders to commit to terms of their proposed loans prior to the underwriting process.[6] The revised documents established a way for lenders to commit to their price offerings, whereby should a borrower be deemed qualified (i.e., pass underwriting),

[2] `http://www.bloomberg.com/apps/news?pid=newsarchive\&sid=aN2DPRuRs93M`

[3] See, for instance, `http://online.wsj.com/article/SB10001424052748703871904575216683364999118.html` and `http://uk.reuters.com/article/idUKN2010696520100920`.

[4] RESPA is a HUD consumer protection statute designed to assist home buyers in shopping for a loan.

[5] `http://www.realtor.org/government_affairs/respa/respa_timeline`.

[6] A 10% price tolerance is given for certain services packaged by lenders such as title insurance and government recording charges.

they will be eligible to purchase a loan package at the cost disclosed in the GFE.

In addition to the regulatory changes, lenders now have access to a larger set of tools that can be used to acquire information about applicants. Experian, one of the big three credit bureaus along with Equifax and Trans Union, has recently acquired RentBureau and now provides updated histories of borrowers' rental payments to large property managers. Equifax now offers lenders an estimate of borrowers' liquid wealth. Fair Isaac, the creator of the widely used FICO credit score, now offers bank-depositor behavior scores based on balances, deposit records, and withdrawal activity.[7] Lenders may also collect additional information about borrowers such as their cellphone payment histories, cars owned, and the type of car insurance they have. As a result of the new types of information being collected, it is becoming increasingly difficult for borrowers to determine whether their application will be accepted.[8]

In parallel to these developments, a consumer's ability to gather information about prices from multiple lenders has increased dramatically. Mortgage comparison sites ranging from Bankrate to Google have made information about lenders' rates readily accessible — information that in the past required lengthy searches by consumers.[9, 10] The increase in the availability of information about lenders' offerings, coupled with the revised rules governing RESPA, particularly regarding price commitment, have naturally intensified competition among lenders.

As the market for mortgages becomes more competitive, in part due to regulatory action and in part due to advances in information technology, it remains unclear what the net effect on underwriting standards will be. How will the tightening of underwriting guidelines by governmental

[7]See `http://finance.yahoo.com/banking-budgeting/article/111250/new-ways-bankers-are-spying-on-you`.

[8]Ibid.

[9]See `http://bankrate.com` and `http://google.com/comparisonads/mortgages`.

[10]A recent 2010 Pew Research Center survey reports that the share of adults who have at least occasionally conducted product or service research online has increased from 49% in 2004 to 58% in 2010; moreover, among respondents who are Internet users, 78% conduct product research online. See `http://pewresearch.org/pubs/1747/e-shopping-researched-product-service-online`.

bodies, increased competition, and access to new types of credit information affect the underwriting process? In this paper, we address this question by studying how lenders choose their underwriting standards in a competitive mortgage market. We study a perfectly competitive market for mortgages where the revised HUD documents (i.e., with price commitments) are taken as given, and where the choice of how much information to acquire about borrowers is entirely in the hands of lenders.

We present and analyze a relatively simple model that conforms with the preceding discussion. In the first stage of the game, firms that sell homogeneous goods (or services) post prices they promise to charge applicants who are ultimately approved. In the second stage, each consumer applies to purchase the good from one of the firms.[11] Next, the firms acquire information about each of their applicants. The outcome of this information acquisition is a bivariate signal indicating that each consumer is either *qualified*, in which case he is permitted to buy the good at the posted price, or *unqualified*, in which case his application is rejected. Consistent with the underwriting landscape, we consider an informational environment in which firms search for information that would disqualify an applicant, i.e. firms search for 'bad news'.[12] The key assumption underlying the model is that contracts are incomplete because the amount of information firms acquire cannot be observed. Since firms cannot commit to information-acquisition levels, they are left to compete only in prices.

We find that firms post the lowest price consistent with zero economic profit in equilibrium. Unfortunately, this low price gives them incentives to acquire excessive amounts of information about their applicants.[13] In other words, all consumers would be better off *ex ante* if the firms

[11] Although the analysis is presented in terms of a mortgage market, it can easily be recast in terms of a labor market where prospective employees apply to firms for jobs.

[12] The Appendix examines both an informational framework in which firms search for 'good news' (Section B) about applicants, and a framework in which the type of search is endogenously determined (Section C).

[13] In the context of an agency model, Khalil (1997) finds that the probability that the principal will audit the agent is higher when the principal cannot commit.

posted higher prices and acquired less information. It is shown that when the marginal cost of information acquisition is relatively high, welfare is larger under a regulatory regime that places severe restrictions on the amount of information firms can collect. Economic discrimination is investigated in a setting with two groups of consumers, a high-risk group and a low-risk group. In the absence of regulation, members of the high-risk group face a higher equilibrium price than members of the low-risk group, but may not face higher rejection rates. Banning price discrimination accentuates quantity discrimination by leading to a situation in which high-risk applicants are subjected to more scrutiny and suffer disproportionately high rejection rates, although their overall welfare rises. Finally, it is shown that when rejected consumers can continue to apply for loans at different firms, the resulting adverse selection seriously undermines the market and can generate a situation in which all parties would be better off if no information was collected at all.

1.1 Related Literature

There is a large and growing literature analyzing recent developments in the mortgage market (see Glaeser and Gottlieb (2010) for a recent survey). Many studies have focused on the role of securitization in influencing loan quality (Elul, 2009; Bubb and Kaufman, 2009; Keys et al., 2010); while others have examined the channels (retail, brokerage, etc.) by which nonprime mortgages originated (Berndt et al., 2010). Bhardwaj and Sengupta (2010b,a) and Demyanyk and Hemert (2010) use loan-level data on mortgage characteristics and default behavior in order to provide a comprehensive overview and examination of subprime underwriting standards. They find a decline in standards in the period from 2004-2006 at least in some dimensions of underwriting. Khandani et al. (2010) and Favilukis et al. (2010) suggest that easy credit market terms, including low down payments and high mortgage approval rates helped facilitate the housing boom-bust cycle. Other works suggest that such easy credit terms themselves may have been the result of agency issues associated with securitization (Keys et al., 2010; Mian and Sufi, 2009, 2010; Mian and Trebbi, 2008). While these works address issues that may have led to the housing crisis, our paper studies the potential effects of some of the recent approaches taken by regulators and firms to tackle the perceived problems. To our knowledge, no prior work provides an analytical study of the impact of competition and price commitment on the mortgage underwriting process.

This paper is also related to the line of research in which firms acquire information about their prospective customers. Papers such as Taylor (2004), Acquisti and Varian (2005), Hermalin and Katz (2006), Calzolari and Pavan (2006), and Conitzer et al. (2010), inspired by observations of price discrimination on the Internet, investigate monopolistic settings in which the purchasing history of consumers can be used to formulate personalized offers.[14] Rather than *price* discrimination by monopolists, however, the current paper investigates *quantity* discrimination in a competitive market. The demand for customer information by a monopolist often does generate undesirable social outcomes, but one hardly expects monopolists to act in the interest of social efficiency. The distortions identified in this paper, on the other hand, arise in a competitive setting where one might plausibly expect efficient information acquisition to obtain.

In another recent paper, Hoppe and Lehmann-Grube (2008), consider a setting of equilibrium price determination in a market where firms collect information about prospective customers. While Hoppe and Lehmann-Grube's analysis is very interesting, the environment and questions they study differ markedly from the ones explored here. In particular, Hoppe and Lehmann-Grube investigate a duopoly setting with differentiated products. They assume that both firms collect a fixed amount of information about applicants and they focus on the characterization of an equilibrium where the firms charge inordinately high prices. In this paper, by contrast, firms sell homogenous goods, and information acquisition levels are endogenously determined. Interestingly, the equilibrium price set

[14] Villas-Boas (2004) extends the analysis to a duopoly setting.

by firms in this environment is inordinately low.

Our findings are reminiscent of – though distinct from – those presented in Hirshleifer (1971). In that celebrated paper, Hirshleifer showed that, given equilibrium prices, the private benefit of information acquisition typically outweighs the social benefit. Indeed, in a pure exchange setting, information may have no social value at all, because it results only in a redistribution of wealth from ignorant agents to informed ones. In the current paper, by contrast, some information acquisition is typically desirable from a social perspective, but contractual incompleteness in tandem with price competition cause firms to collect too much information in equilibrium.

Our paper also adds an important caveat to early privacy articles by Hirshleifer (1980), Stigler (1980), and Posner (1981). These authors argued that privacy should not be a concern in a competitive setting where market forces ensure that the marginal benefit of information acquisition equals the marginal cost. The central theme of this paper is that if information acquisition is not observable, then competitive pressure will lead to a divergence between the marginal private benefit of information acquisition and the marginal social benefit. In such a setting, firms will possess incentives to systematically collect the wrong amount of information about prospective customers, resulting in too little trade in equilibrium.

2 The Model

Consider a mortgage market in which there is uncertainty about consumer characteristics.[15] The supply side of the market is composed of at least two identical risk-neutral expected profit maximizing firms. The demand side of the market consists of a continuum of *ex ante* identical consumers

[15]Although the discussion is framed in terms of a mortgage market, the analysis presented below can apply to numerous settings including: a life or health insurance market in which there is uncertainty about genetic factors, a rental housing market in which there is uncertainty about the risk of property damage, and a college education market in which there is uncertainty about scholastic aptitude. In a labor-market setting, employers might be uncertain about the productivity of potential workers.

with unit measure. Each consumer is a risk-neutral expected utility maximizer who receives incremental utility of $v > 0$ from consuming one unit of the good and zero from consuming additional units. Each consumer is one of two possible types. In particular, the cost of supplying the good to him either turns out to be low, $c_L \geq 0$, or high, $c_H > c_L$. The realization of a consumer's type is not contractually verifiable. Also, in order for the model to be interesting, it is assumed that $c_H > v > c_L$. In other words, it is efficient to serve only low-cost consumers.

The proportion of high-cost consumers in the population is $\lambda > 0$. Information is initially incomplete and symmetric. In particular, consumers do not know their own types or, equivalently, they do not know the criteria firms use to evaluate information.[16] Hence, it is appropriate to think of a single representative consumer whose probability of being a high-cost type is λ.

At the beginning of the game, each firm j announces a price[17] $p_j \in \mathbb{R}_+$ at which it commits to sell a unit of the good to a consumer whose application is ultimately approved.[18] These price announcements are made publicly and simultaneously. The consumer then either *applies* to purchase the good (the mortgage) from one of the firms or chooses not to apply to any firm. If he does not apply for the good, then the game ends and all parties receive their reservation payoffs of zero.[19]

If a consumer applies for a mortgage, then the firm he selects may acquire information about him. Specifically, the firm chooses a 'sample size' or search intensity $n \geq 0$.[20] The search intensity, n, is unobservable and unverifiable. The cost to the firm of acquiring information about an applicant is kn, where $k > 0$. A firm that chooses search intensity n receives n conditionally independent

[16] In the mortgage market, consumers may know their credit scores. However, lenders employ many other measures to help determine whether a consumer is qualified for a loan.

[17] This price can correspond to the overall cost of the loan package, including the rate and associated fees such as origination charges.

[18] Mortgage rates and fees to ultimately approved applicants are already available online. See, for instance, `www.amerisave.com` and `google.com/comparisonads/mortgages`.

[19] We assume that a consumer's cost of applying is negligible, though it need not be zero. Our results go through when it is no larger than the expected gain from applying.

[20] The sample size, n, is treated as a continuous choice variable for convenience. Also, it is assumed that the technology involves simultaneous rather than sequential sampling. All results remain qualitatively unchanged under sequential sampling.

Bernoulli' signals $X_1, \ldots, X_n$, where

$$\Pr\{X_i = 1|c\} = \begin{cases} 1, & \text{if } c = c_L, \\ 1-\alpha, & \text{if } c = c_H \end{cases}$$

The parameter $\alpha \in (0,1)$ is intrinsic signal strength. If $\alpha = 1$, then a single signal is fully informative, and if $\alpha = 0$, then the signals contain no information at all. This process is interpreted as follows. Each firm chooses a file containing n records, $X_1, \ldots, X_n$, (e.g., a payment or job history) for each of its applicants. Each record in the file is either positive ($X_i = 1$) or negative ($X_i = 0$). Since the probability of a false negative is zero in this setting, it is appropriate to regard the firm as searching records for 'bad news' about its applicants.[21]

Note that it is possible to summarize all the information contained in an applicant's file with the sufficient statistic

$$S_n \equiv \min\{X_1, \ldots, X_n\}.$$

Specifically, if $S_n = 0$, then at least one of the records was negative and the applicant is certainly type c_H, and if $S_n = 1$, then all the records were positive and the applicant is type c_L with probability

$$\frac{(1-\lambda)}{\lambda(1-\alpha)^n + (1-\lambda)} > (1-\lambda).$$

If $S_n = 0$, then the applicant is regarded as *unqualified*, and if $S_n = 1$, then he is regarded as *qualified.*

After acquiring information, a firm must decide whether to approve the consumer's application (i.e., loan him the mortgage at the posted price). Approval results in a payoff of $v - p_j$ for the consumer and an expected payoff of $p_j - E[c|S_n] - kn$ for the firm. Rejection results in a payoff of zero for the consumer and $-kn$ for the firm.

[21] The Appendix considers the analogous setting in which firms search for 'good news' (Section B) as well as a setting in which the type of search a firm conducts is determined endogenously (Section C).

It is notationally convenient to define the positive constant

$$m \equiv -\frac{k}{\ln(1-\alpha)}.$$

This is a measure of the efficacy of the information-acquisition technology. Lower values of m correspond to better technologies involving low sampling costs and/or high intrinsic signal strength.

3 The First-Best Solution

In this section, the socially efficient information acquisition and allocation policy is characterized. To this end, suppose that a planner, who is interested in maximizing the expected utility of consumers, operated the firms subject to a zero-profit constraint. In particular, define the function

$$AC(n) \equiv \frac{\lambda(1-\alpha)^n c_H + (1-\lambda)c_L + kn}{\lambda(1-\alpha)^n + (1-\lambda)}. \tag{1}$$

This is the expected cost of gathering information about a consumer and approving him for the mortgage conditional on observing $S_n = 1$. In other words, it is the cost to a firm per accepted application, or its average cost of operation. A firm that makes zero expected profit must charge a price p to qualified applicants and select a search intensity n such that $p = AC(n)$.

Given the information-acquisition technology, the planner should clearly pursue one of the following three possible strategies:

Policy 1. Acquire information $n > 0$ about the consumers and sell to the qualified ones at a price of $AC(n)$.

Policy 2. Acquire no information and sell to all consumers at a price of $\lambda c_H + (1-\lambda)c_L$.

Policy 3. Acquire no information and sell to no-one.

Policy 3 corresponds to abandoning the market and obviously yields welfare of zero. If the planner elects not to abandon the market, then she must solve the following problem in order to choose optimally between Policies 1 and 2:

$$\max_{(p,n)} U(p,n) \equiv (\lambda(1-\alpha)^n + (1-\lambda))\,(v-p) \quad \text{s.t. } p = AC(n).$$

A consumer's expected utility, $U(p,n)$, is the product of two terms, the probability of being approved and the surplus from obtaining the loan. Note that the probability of approval is decreasing in the amount of information acquisition, n. Hence, the more the firm knows about a consumer, the less likely it is to approve him for the mortgage. This, however, does not imply that it is necessarily optimal to set $n = 0$. Specifically, there is generally a trade-off between higher values of n and lower values of p deriving from the zero-profit constraint. To see this, define welfare by $W(n) \equiv U(AC(n), n)$. The planner's problem can then be written as:

$$\max_{n \geq 0} W(n) = \lambda(1-\alpha)^n(v - c_H) + (1-\lambda)(v - c_L) - kn. \tag{2}$$

The first term is negative and represents the social cost of allocating the good to the high-cost consumers who are mistakenly regarded as qualified; the second term is positive and represents the social benefit of allocating the good to the low-cost consumers; and the third term is the cost of information acquisition. Policy 2 dominates Policy 1 if and only if a corner solution to (2) obtains at $n = 0$. At such a solution, the marginal cost of mistakenly allocating the good to a consumer is less than the marginal cost of acquiring information about him, while these costs are equalized at an interior solution.

Differentiating $W(n)$ yields

$$W'(n) = \ln(1-\alpha)\lambda(1-\alpha)^n(v - c_H) - k.$$

Observe that $W'(n)$ decreases with n and is negative for sufficiently large n. An interior solution to (2) obtains, therefore, if and only if $W'(0) > 0$, or

$$m < \lambda(c_H - v). \tag{3}$$

If (3) holds, then the solution, n^*, is defined implicitly by the condition

$$\lambda(1-\alpha)^{n^*}(c_H - v) = m, \tag{4}$$

and if (3) does not hold, then the solution to (2) is $n^* = 0$. In other words, consumers are willing to undergo a stricter underwriting process in exchange for a lower rate on their mortgage if and only if (3) holds. This makes sense. Consumers prefer Policy 1 to Policy 2 when the information-acquisition technology is relatively good (i.e., m is relatively small) or the social cost of misallocation is relatively high (i.e., $\lambda(c_H - v)$ is large) because these are the situations in which the zero-profit price, $AC(n)$, declines rapidly.

While condition (3) is necessary and sufficient for Policy 1 to dominate Policy 2, it remains to determine the conditions under which Policy 3 (abandoning the market) is optimal. As a first step in answering this question, consider the following definition.

Definition 1 (Viability)**.** The market is said to be *ex ante* viable if

$$v > \lambda c_H + (1-\lambda)c_L.$$

The market is *ex ante* viable if each consumer's valuation for the good exceeds the unconditional expected cost of supplying it to him. Observe that Policy 3 cannot be optimal in this case because Policy 2 (acquiring no information and approving everyone) delivers positive welfare. Even if the market is not *ex ante* viable, however, Policy 1 may be preferable to abandoning the market.

Lemma 1 (The Abandonment Boundary)**.** *If the market is not ex ante viable, then there exists a unique number $m^\dagger \in (0, \lambda(c_H - v))$ such that Policy 1 delivers positive welfare* iff $m < m^\dagger$.

Proposition 1 (The First-Best Solution)**.** *The socially efficient plan is characterized as follows.*

(i) *If the market is* ex ante *viable and $m < \lambda(c_H - v)$, or if the market is not* ex ante *viable and $m < m^\dagger$, then Policy 1 is optimal; i.e., the planner should acquire information in accordance with (4) and sell to qualified consumers for $p = AC(n^*)$.*

(ii) *If the market is* ex ante *viable and* $m \geq \lambda(c_H - v)$*, then Policy 2 is optimal; i.e., the planner should acquire no information and sell to everyone for* $p = \lambda c_H + (1-\lambda)c_L$*.*

(iii) *If the market is not* ex ante *viable and* $m \geq m^\dagger$*, then Policy 3 is optimal; i.e., the planner should acquire no information and sell the good to no-one.*

This result is intuitive. It says that the market should be abandoned if and only if it is not *ex ante* viable and information is too costly. If this is not the case, then it is efficient either to acquire information about consumers and sell to the qualified ones for $AC(n^*)$, or to acquire no information and sell to all consumers for $\lambda c_H + (1-\lambda)c_L$. As noted above, the most interesting aspect of this finding is that when Policy 1 is optimal, consumers are willing to be held to stricter underwriting standards in an effort to secure a loan package at a lower rate.

4 Market Equilibrium

The market game has four stages: price announcements by firms, application by consumers, information acquisition, and allocation of the good by firms. As usual, derivation of a pure-strategy subgame perfect Nash equilibrium (referred to as just an equilibrium below) requires analyzing these stages in reverse order.

When deciding on its information acquisition and allocation plan, a firm should pursue one of the same three alternatives identified in Section 3: acquire information about its applicants and sell to the qualified ones; acquire no information and sell to all applicants; or acquire no information and sell to no-one.

Unless it is optimal to abandon the market, a firm posting price p will choose n to maximize

$$\Pi(p,n) \equiv \lambda(1-\alpha)^n(p-c_H) + (1-\lambda)(p-c_L) - kn.$$

Define the critical price

$$p^{\dagger} \equiv c_H - \frac{m}{\lambda}. \tag{5}$$

For $p < p^{\dagger}$, the optimal search intensity for the firm is defined implicitly by the following first-order condition

$$\lambda(1-\alpha)^{\overline{n}(p)}(c_H - p) = m, \tag{6}$$

and for $p \geq p^{\dagger}$, the optimal search intensity $\overline{n}(p) \equiv 0$.

Observe that for $p < p^{\dagger}$, lower prices induce firms to acquire more information about each applicant, resulting in a lower probability of sale. The question is which prices consumers find attractive.

Definition 2 (Relevant Prices)**.** A price $p \in \mathbb{R}_+$ is said to be relevant if $p < v$ and $\Pi(p, \overline{n}(p)) \geq 0$.

Since a firm will reject all of its applicants without acquiring information if $\Pi(p, \overline{n}(p)) < 0$, only relevant prices yield an applicant positive expected utility in the continuation equilibrium. In particular, a consumer's expected utility from applying to purchase the good at relevant price p is

$$U(p, \overline{n}(p)) = \left(\lambda(1-\alpha)^{\overline{n}(p)} + (1-\lambda)\right)(v - p). \tag{7}$$

The first term in this expression is the probability of having his application approved, which is increasing in p (due to looser underwriting standards), and the second term is the surplus from acceptance, which is decreasing in p. The following lemma indicates that even though lower prices involve tighter underwriting standards, consumers will apply to one of the firms posting the lowest relevant price in the market.

Lemma 2 (Demand)**.** *A consumer's expected continuation payoff, $U(p, \overline{n}(p))$, is strictly decreasing in p.*

In light of Lemma 2, if a firm posts the lowest relevant price p, then in the continuation equilibrium it earns expected profit per application of

$$\Pi(p, \overline{n}(p)) = \lambda(1-\alpha)^{\overline{n}(p)}(p - c_H) + (1-\lambda)(p - c_L) - k\overline{n}(p) \tag{8}$$

Next, observe that in equilibrium $\Pi(p, \overline{n}(p))$ must equal zero. It cannot be negative, or a firm posting p could profitably deviate by offering a non-relevant price. On the other hand, if $\Pi(p, \overline{n}(p)) > 0$, then one of the least profitable firms in the market would benefit by deviating to a price slightly less than p and attracting all the applicants.

Lemma 3 (The Competitive Price)**.** *If the market is* ex ante *viable or if $m < m^\dagger$, then there exists a unique relevant price $\overline{p}$ such that $\Pi(\overline{p}, \overline{n}(\overline{p})) = 0$. If the market is not* ex ante *viable and $m \geq m^\dagger$, then no relevant price exists.*

This lemma says that there is a unique relevant price $\overline{p}$ satisfying $\overline{p} = AC(\overline{n}(\overline{p}))$ if and only if there is positive surplus available in the market (i.e., first-best welfare is not zero). It is now possible to characterize the equilibrium outcome of the game.

Proposition 2 (Market Equilibrium)**.** *The unique equilibrium outcome is characterized as follows.*

(i) *If the market is* ex ante *viable and $m < \lambda(1-\lambda)(c_H - c_L)$, or if the market is not* ex ante *viable and $m < m^\dagger$, then: at least two firms post the price $\overline{p} = AC(\overline{n}(\overline{p}))$; no firm posts a lower price; consumers apply to the low-price firms; the firms acquire information $\overline{n}(\overline{p}) > 0$ about their applicants and sell to the qualified ones.*

(ii) *If the market is* ex ante *viable and $m \geq \lambda(1-\lambda)(c_H - c_L)$, then: at least two firms post the price $\overline{p} = \lambda c_H + (1-\lambda)c_L$; no firm posts a lower price; consumers apply to the low-price firms; the firms acquire no information and sell to all applicants.*

(iii) *If the market is not* ex ante *viable and $m \geq m^{\dagger}$, then equilibrium payoffs to all parties are zero because all firms post non-relevant prices.*

This result parallels Proposition 1 in several respects. In particular, one of three possible types of market equilibrium prevails depending on parameter values. There may be a *Type 1 equilibrium* in which firms price competitively, acquire information about their applicants, and sell to the qualified ones; or there may be a *Type 2 equilibrium* in which firms price competitively, acquire no information, and sell to everyone; or there may be a *Type 3 equilibrium* in which the market is inactive.

These three types of equilibria correspond closely to the three potentially optimal policies identified in Proposition 1. Indeed, the parameter values giving rise to a Type 3 equilibrium in which the market is inactive are the same as those under which Policy 3 (abandoning the market) is efficient. On the other hand, while Type 1 and Type 2 equilibria are similar in spirit to implementation of Policy 1 and Policy 2 respectively, there is a key difference concerning the incentives for information acquisition across the two settings that is explored in the next section.

5 The Equilibrium Level of Information Acquisition

The following lemma characterizes the function $AC(n)$ for parameter values under which the market equilibrium involves positive information acquisition.

Lemma 4 (Minimum Average Cost)**.** *If the market is* ex ante *viable and $m < \lambda(1-\lambda)(c_H - c_L)$ or if the market is not* ex ante *viable and $m < m^{\dagger}$, then $AC(n)$ is U-shaped and*

$$\overline{n}(\overline{p}) = \underset{n \geq 0}{\operatorname{argmin}}\, AC(n).$$

With this lemma in hand, it is possible to prove the following key result.

Proposition 3 (Excessive Information Acquisition)**.** *If the market is* ex ante *viable and* $m < \lambda(1-\lambda)(c_H - c_L)$*, or if the market is not* ex ante *viable and* $m < m^\dagger$*, then* $\overline{n}(\overline{p}) > n^*$ *and* $AC(\overline{n}(\overline{p})) < AC(n^*)$*. That is, firms collect too much information about their applicants and price too low in any Type 1 equilibrium.*

Proposition 3 is easily understood. It arises from a divergence between the social and private cost of misallocation. The social cost of awarding the good to a high-cost consumer is $c_H - v$ while the private cost to a firm from misallocation is $c_H - \overline{p}$. In a Type 1 equilibrium, competition ensures that $\overline{p} < v$, and hence, firms have higher incentives to acquire information about their applicants than is socially efficient. In particular, the firms do not account for the positive consumer surplus $v - \overline{p}$ derived from selling the good to a high-cost consumer.[22]

Note from Lemma 4 that the equilibrium price $\overline{p}$ is the lowest price that firms can post and still break even. Indeed, $\overline{p}$ is 'too low' in the sense that consumers would be happier to face looser underwriting standards and pay a higher price. In particular, a search intensity of n^* and price of $p = AC(n^*)$ would generate an *ex ante* Pareto improvement since all consumers would be better off and firms would still make zero expected profit. The problem here derives from the unobservability of the search intensity, n. Because n is not contractible, firms cannot commit to investigate applicants efficiently. Specifically, given that the firms will acquire information according to $\overline{n}(p)$, consumers will apply for the mortgage that has the lowest offered price. Hence, the

[22] It is possible to achieve efficiency in a Type 1 equilibrium by considering a richer but less realistic contract space. In particular, suppose each firm j promises to give each of its applicants an up-front payment of r_j and to charge the qualified ones p_j for the good. The equilibrium of this game will involve $\overline{r}$ equaling first-best welfare, $\overline{p} = v$, and $\overline{n}(\overline{p}) = n^*$. In other words, in equilibrium the consumers 'sell the expected surplus' to the firms, which generates the correct incentives for information acquisition. Contracts that involve positive payments from the firms to unqualified applicants, however, are uncommon and unrobust. For instance, if (as is considered in Section 8 below) a consumer whose application is rejected at one firm can apply at another, then paying unqualified applicants will certainly not give rise to an efficient equilibrium outcome. Additionally, in a mortgage market, many types of transfers are prohibited. For example, it is illegal to artificially inflate the price of the property and return some of the money to the buyer at closing. It is also illegal for a seller to directly provide a buyer funds for a down payment without the knowledge of the lender. See, for instance, `http://home-equity.interest.com/content/articles/home-equity\_story.asp?story\_id=1000035150\&ID=interest`.

combination of competition and the non-contractibility of n result in a price that is too low and underwriting standards that are too strict relative to the social optimum.

6 Full Home Ownership

The Federal Housing Administration runs several programs designed to promote home ownership. In most cases, FHA loans are mortgages obtained with the help of the FHA. With a small down payment, often as low as 3.5%, buyers can purchase a home. Additionally, an FHA loan is insured against default by the government – the FHA guarantees that a lender will not need to write off a loan if the borrower defaults, as the FHA will pay for it. The requirements are relatively loose for such a loan, though the loan amount is capped.[23] The provision of FHA loans raises an interesting question regarding who should be able to purchase a home.

Since firms possess incentives to acquire too much information about their applicants in a Type 1 equilibrium, it is interesting to investigate a (relatively extreme) setting in which all consumers are approved; i.e., a setting in which firms cannot disqualify applicants.[24] Clearly, if the market is not *ex ante* viable, then this assignment of rights will cause the market to shut down. On the other hand, if the market is *ex ante* viable, then requiring the firms to serve all consumers may generate an *ex ante* Pareto improvement relative to a Type 1 equilibrium.

Proposition 4 (Efficient Assignment of Rights)**.** *Suppose that the market is* ex ante *viable.*

(i) *If $m \in [\lambda(c_H - v), \lambda(1-\lambda)(c_H - c_L))$, then approving all consumers is socially optimal and generates strictly higher welfare than a Type 1 equilibrium.*

(ii) *There exists $\epsilon \in (0, \lambda(c_H - v))$ such that $m < \epsilon$ implies that a Type 1 equilibrium in which firms*

[23] See `http://www.fha.com/`.

[24] Other (less blunt) types of regulation such as taxing information acquisition or capping it at some level may not be feasible if n is not observable.

have the right to investigate applicants generates higher welfare than approving all consumers.

This result says that it is better to qualify all consumers when the market is *ex ante* viable and the information-acquisition technology is not very good or the social cost of misallocation $c_H - v$ is small. This makes sense. These are precisely the cases in which the socially-efficient search intensity, n^*, is small. Hence, the inefficiency deriving from allowing no information acquisition ($n = 0$) is less than that deriving from the excessive information acquisition ($n = \overline{n}(\overline{p})$) that would occur in a Type 1 equilibrium. On the other hand, as the information-acquisition technology becomes perfect, the social cost from excessive information acquisition vanishes, and it is better to permit firms to investigate their applicants.

7 Discrimination

In order to explore the interplay between information acquisition and economic discrimination, consider a variant of the model in which the population is composed of two identifiable groups of consumers (e.g. males and females, minorities and non-minorities, or young and old). Suppose that one group has a larger proportion of high-cost individuals than the other group, $\lambda_H > \lambda_L$. Denote the fraction of the population in the high-risk group by $\theta \in (0, 1)$.

Left unregulated, firms will naturally discriminate economically between the two groups both with respect to price and information acquisition. Suppose in this case that a Type 1 equilibrium obtains in both market segments and denote the prices posted to the high and low-risk groups respectively by $\overline{p}_H$ and $\overline{p}_L$.[25]

Lemma 5 (Economic Discrimination)**.** *In any Type 1 equilibrium, high-risk applicants face a higher price and receive lower expected utility than low-risk applicants; i.e.,* $\overline{p}_H > \overline{p}_L$ *and* $U_H(\overline{p}_H, \overline{n}_H(\overline{p}_H)) <$

[25]It is straightforward to verify that a type 1 equilibrium will obtain in both market segments if and only if either $v > \lambda_H c_H + (1 - \lambda_H) c_L$ and $m < \min\{\lambda_L(1 - \lambda_L)(c_H - c_L), \lambda_H(1 - \lambda_H)(c_H - c_L)\}$, or $m < m_H^\dagger$.

$U_L(\overline{p}_L, \overline{n}_L(\overline{p}_L))$.

The fact that consumers in the high-risk group have lower expected equilibrium utility than those in the low-risk group is not surprising. It is, however, somewhat striking that high-risk applicants are not necessarily investigated more intensively in equilibrium. While the direct effect on equilibrium search intensity from a rise in λ is positive, there is a countervailing indirect effect associated with the rise in the equilibrium price. Hence, while high-risk applicants fare worse than low-risk ones on average, they do not necessarily face a higher probability of rejection.

In the U.S. and numerous other countries it is illegal to price discriminate with respect to characteristics such as gender, race, or age in many markets, (e.g., housing, credit, or labor markets). It is interesting, therefore, to investigate the welfare consequences arising from a prohibition on price discrimination. Let $\overline{p}_M$ denote the equilibrium price that obtains when price discrimination is prohibited. Also, suppose that firms must substantiate rejection decisions by providing verifiable evidence that rejected applicants are actually unqualified.[26]

Proposition 5 (Prohibiting Price Discrimination)**.** *Banning price discrimination raises the equilibrium expected utility of high-risk applicants, lowers the equilibrium expected utility of low-risk applicants, and induces firms to investigate high-risk applicants more intensively than low-risk ones.*

This result says that banning price (or wage) discrimination does unambiguously raise the *ex ante* welfare of high-risk consumers (or workers) and reduce the *ex ante* welfare of low-risk ones. Interestingly, it also says that prohibiting price discrimination accentuates quantity discrimination.[27]

In particular, high-risk applicants are subjected to more intense scrutiny and suffer disproportionately high rejection rates, $\overline{n}_H(\overline{p}_M) > \overline{n}_L(\overline{p}_M)$. The intuition is straightforward. Because

[26] Without this assumption, the equilibrium price would be $\overline{p}_M = \overline{p}_L$, and firms would reject all applications by high-risk consumers without acquiring any information about them.

[27] There is a large empirical literature documenting quantity discrimination in markets where price discrimination by sex, race, or age is illegal. See, for example, Munnell (1996).

$\overline{p}_M \in (\overline{p}_L, \overline{p}_H)$, the net cost to a firm of misallocating the good to a high-risk applicant rises and the net cost of misallocating to a low-risk applicant falls when price discrimination is prohibited. Hence, firms have stronger incentives to investigate high-risk applicants and weaker incentives to investigate low-risk ones. Moreover, because the cost of misallocating the good is $c_H - \overline{p}_M$ for both groups, and because there is a larger fraction of high-cost consumers in the high-risk group, the incentive to investigate high-risk applicants is unambiguously higher when price discrimination is banned.

8 Adverse Selection

In this section, the original setting is modified by supposing that rejected applicants remain in the market for a loan and reapply to other firms. This requires some modification of the basic model presented in Section 2. In particular, it is necessary to add a dynamic component and (for the sake of tractability) to suppose that each firm is small relative to the market.

Consider a time horizon running from $-\infty$ to $+\infty$. In each period t, a continuum of consumers with total measure equal to one enters the market. Each consumer wishes to acquire one mortgage which he values at v. A fraction λ of the entering consumers have cost $c_H > v$ and the complementary fraction have cost $c_L < v$. Consumers who receive a mortgage exit the market. Consumers who have applications rejected exit the market receiving payoffs of zero with probability $(1 - \psi) \in (0, 1)$ and remain in the market with probability ψ in each period.

There is a continuum of identical firms with total measure greater than $1/(1 - \psi)$ (the largest possible measure of consumers in the market). Each firm is financially constrained so that it can provide at most one mortgage per period.[28]

[28]It is important that there is always excess capacity in the market so that a firm that posts a price above the competitive level does not attract an applicant.

At the beginning of each period t, the firms simultaneously post prices. Next, the consumers in the market simultaneously decide whether to apply to one of the firms or to remain idle in the current period. If a consumer applies, then the firm to which he applies acquires information and either approves or rejects his application. If the firm approves his application, then trade takes place and the consumer exits the market. If the firm rejects the consumer's application, then the consumer remains in the market with probability ψ in which case he may apply to a different firm in the next period. Firms do not share information about rejected applications. All parties possess discount factor $\delta < 1$.

For notational convenience, define

$$\phi \equiv 1 - (1 - \alpha)^n$$

to be the probability of detecting a high cost consumer (called the underwriting intensity). Let μ_t denote the firms' belief about the fraction of high-cost consumers in the applicant pool at the beginning of period t. The solution concept is defined as follows.

Definition 3 (Steady-State Markov Equilibrium)**.** A steady-state Markov equilibrium consists of a price function, $\hat{p}(\mu_t)$, an underwriting-intensity function, $\hat{\phi}(p, \mu_t)$, and beliefs by market participants satisfying the following conditions.

(i) It is optimal for all firms to post the price $\hat{p}(\mu_t)$ and screen according to $\hat{\phi}(p, \mu_t)$ in every period.

(ii) It is optimal, given his beliefs, for a consumer to apply for the good at the lowest price posted in every period.

(iii) On the path of play, beliefs are correct and stationary; i.e., there exists $\hat{\mu} \in [0, 1]$ such that $\mu_t = \hat{\mu}$ for all t.

The first thing to note is that the actions of an individual firm in period t have negligible impact on the composition of the applicant pool and, therefore, do not influence future states $\mu_{t+1}, \mu_{t+2}, \ldots$.

Hence, in a Markov equilibrium, firms simply maximize current profit in each period. This means that the underwriting intensity function of a firm that posts price p is found by solving

$$\max_{\phi \geq 0} \Pi(p, \phi; \mu_t) = (1-\phi)\mu_t(p-c_H) + (1-\mu_t)(p-c_L) + m\ln(1-\phi).$$

The first-order condition yields

$$\hat{\phi}(p, \mu_t) = \begin{cases} 1 - \dfrac{m}{\mu_t(c_H - p)}, & \text{if } m < \mu_t(c_H - p) \\ 0, & \text{otherwise.} \end{cases} \tag{9}$$

Next, if consumers believe that market prices will remain constant over time (which is true in a steady-state), then they will apply to purchase the good at every opportunity. Since (by Lemma 2) consumers apply to the firms posting the lowest price in any period, equilibrium profits are zero. The equilibrium price function, $\hat{p}(\mu_t)$, is, therefore, defined implicitly by the condition

$$\Pi(\hat{p}(\mu_t), \hat{\phi}(\hat{p}(\mu_t), \mu_t); \mu_t) = 0. \tag{10}$$

On the path of play in a steady-state Markov equilibrium, the applicant pool at the beginning of each period consists of the new arrivals in the market along with all the high-cost consumers who have not previously had their applications approved and have not otherwise exited the market. (Low-cost consumers are always approved in the period when they arrive.) The measure of high-cost consumers in the applicant pool, therefore, is

$$\lambda\left(1 + \psi\hat{\phi} + (\psi\hat{\phi})^2 + \ldots\right) = \frac{\lambda}{1-\psi\hat{\phi}},$$

where $\hat{\phi} = \hat{\phi}(\hat{p}(\hat{\mu}), \hat{\mu})$. The proportion of high-cost consumers in the applicant pool in a steady-state Markov equilibrium, therefore, is

$$\hat{\mu} = \frac{\lambda}{1-(1-\lambda)\psi\hat{\phi}}. \tag{11}$$

Observe that adverse selection (i.e., $\hat{\mu} > \lambda$) obtains unless $\psi = 0$ (all consumers exit the market after one period) or $\hat{\phi} = 0$ (applicants are not screened).

Setting $\mu_t = \hat{\mu}$ in (9) and (10) yields three equations in the steady-state equilibrium variables $\hat{p}$, $\hat{\phi}$, and $\hat{\mu}$. A steady-state Markov Equilibrium corresponds to a solution to this system of equations satisfying $\hat{p} < v$. In order to characterize such a solution, substitute from (9) into (11) to get the function

$$\mu(p, \psi) \equiv \frac{\lambda(c_H - p) - (1-\lambda)\psi m}{(1-(1-\lambda)\psi)(c_H - p)}, \tag{12}$$

for $p < p^\dagger$ and $\mu(p,\psi) \equiv \lambda$ for $p \geq p^\dagger$, for all $p \in [c_L, c_H]$ and $\psi \in [0,1]$. Now, for a given value of ψ, consider the function

$$\gamma(p) \equiv \Pi(p, \hat{\phi}(p, \mu(p,\psi)); \mu(p,\psi)), \quad p \in [c_L, c_H].$$

Any value $\hat{p} < v$ for which $\gamma(\hat{p}) = 0$ constitutes a steady-state Markov Equilibrium price. The corresponding equilibrium proportion of high-cost consumers in the applicant pool is $\mu(\hat{p}, \psi)$ and the equilibrium underwriting intensity is $\hat{\phi}(\hat{p}, \mu(\hat{p}, \psi))$.

Proposition 6 (Existence and Characterization)**. (i)** *If $\gamma(v) > 0$ and $m < \lambda(1-\lambda)(c_H - c_L)$, then there exists a unique steady-state Markov equilibrium outcome. In particular, firms screen their applicants and sell only to the ones who appear qualified.*

(ii) *If $\gamma(v) > 0$ and $m \geq \lambda(1-\lambda)(c_H - c_L)$, then there exists a unique steady-state Markov equilibrium outcome. In particular, firms do not screen their applicants; i.e., $\hat{\phi} = 0$, $\hat{\mu} = \lambda$, and $\hat{p} = \lambda c_H + (1-\lambda)c_L$.*

(iii) *If $\gamma(v) \leq 0$, then no steady-state Markov equilibrium exists.*

Consider the parameter ψ, the probability that a rejected applicant remains in the market. If $\psi = 0$, then the steady-state Markov equilibrium outcome characterized in Proposition 6 corresponds exactly to the equilibrium outcome of the static game analyzed in section 4. As ψ rises, however, adverse selection becomes increasingly problematic if the equilibrium involves information acquisition because the stock of rejected (high-cost) consumers in the applicant pool grows.

Proposition 7 (Adverse Selection)**.** *If $\psi = 0$, then $\hat{p} = \overline{p}$, $\hat{\mu} = \lambda$, and*

$$\hat{\phi} = 1 - (1-\alpha)^{\overline{n}(\overline{p})}.$$

Moreover, if $m < \lambda(1-\lambda)(c_H - c_L)$, then the following comparative statics obtain for all $\psi \in [0,1]$:

(i) $\partial\hat{p}/\partial\psi > 0$,

(ii) $\partial\hat{\mu}/\partial\psi > 0$,

(iii) $\partial\hat{\phi}/\partial\psi > 0$.

This result says that when $\psi > 0$, systematic differences between a steady-state Markov equilibrium with information acquisition and a Type 1 equilibrium of the static game emerge. Specifically, $\psi > 0$ implies a higher proportion of high-cost consumers in the applicant pool, a higher underwriting intensity, and a higher price in equilibrium. The direct effect of a rise in ψ is to raise the stock of rejected consumers who remain in the applicant pool. This, in turn, increases incentives for firms to screen. Finally, the price rises to account both for the rise in information-acquisition costs and the fact that more high-cost applicants are (in spite of the increased underwriting intensity) mistakenly allocated the good.

In order to highlight the impact of adverse selection, consider the limiting situation in which $\psi \to 1$. In this case, the zero-profit condition (10) can be recast as

$$\hat{p} = \lambda c_H + (1-\lambda)c_L - m\ln(1-\hat{\phi})\left(\frac{\lambda}{1-\hat{\phi}} + (1-\lambda)\right).$$

This is disturbing. First of all, it implies that a steady-state Markov equilibrium with information acquisition does not exist unless the market is *ex ante* viable, and even when it exists, it is very inefficient. To see this, first observe that the equilibrium price equals the unconditional expected cost of selling to a new consumer plus the cost of screening all applicants. This holds for the following reasons. First, all $(1-\lambda)$ of the low-cost consumers purchase the good as soon as they enter the market. Second, the stock of high-cost consumers in the market at the beginning of each period is $\lambda/(1-\hat{\phi})$, and the measure of these who are mistakenly allowed to purchase the good is λ. Hence, the total revenue earned in the market, $\hat{p}$, equals the total cost of production, $\lambda c_H + (1-\lambda)c_L$, plus the cost of screening all applicants, $-m\ln(1-\hat{\phi})\left(\lambda/(1-\hat{\phi}) + (1-\lambda)\right)$. Observe, however, that if every firm stopped screening, then the competitive price in the new steady state would be $\lambda c_H + (1-\lambda)c_L$. In other words, as $\psi \to 1$, the resources used in screening are completely wasted. Of course, it is not an equilibrium for the firms to stop acquiring information. Hence, the equilibrium outcome has a Prisoner's-Dilemma flavor — all firms devote resources to screening applicants and yet each firm makes its share of mistakes and sells to just as many high-cost consumers as in a setting where no firm collected any information at all.

The problem here stems from a classical externality. When a firm chooses its underwriting intensity, it does not account for the adverse impact of its decision on the other firms in the industry. Specifically, when a firm learns that an applicant is high-cost and rejects him, it returns him to the applicant pool where he will continue to apply to other firms. Hence, when rejected consumers remain in the market, there is an even sharper divergence between the social and private benefit of information acquisition. In particular, when ψ is sufficiently high, then it is socially optimal to acquire no information at all. Nevertheless, firms possess incentives to screen applicants and dump their rejects back into the applicant pool.

This discussion points to an important distinction between the acquisition and the sharing of information. While it often is efficient to induce firms to collect less information, it may be important to allow them to 'share' the information they collect.[29] Hence, it may make sense to concentrate consumer data in a few key repositories with easy access by all firms in the industry.

[29] Pagano and Jappelli (1993) stress the importance of information sharing in credit markets.

9 Conclusion

A theory of information acquisition in competitive mortgage markets with incomplete contracts was explored. Firms were assumed to demand cost-relevant information about the consumers applying for loans and to use this information to decide which of them are qualified. The consumers also possess some uncertainty about whether or not their application will be approved and, therefore, face a trade-off. Specifically, the price a consumer pays for the good – conditional on being judged qualified to buy it – initially decreases in the amount of information firms acquire about him. On the other hand, the probability of being judged unqualified is increasing in the level of information acquisition. There is typically a unique efficient level of underwriting intensity that is characterized by equality between the marginal social cost of misallocating the good and the marginal social cost of acquiring more information.

It was shown that if firms search for bad news about applicants in a setting where information acquisition levels are non-contractible, then they will compete 'too aggressively' in the sense that they post the lowest price consistent with zero economic profit. Unfortunately, this low price gives them incentives to acquire excessive amounts of information. In other words, all consumers would be better off *ex ante* if the firms posted higher prices and acquired less information. This inefficient level of underwriting intensity arises because firms do not account for the consumer surplus earned by high-cost applicants who are mistakenly sold the good at the competitive price. Hence, there is a divergence between the social and private benefit of information acquisition. In situations where the efficient level of information acquisition is low, it may even be socially beneficial to qualify all consumers rather than suffer the excessive information acquisition that would otherwise result.[30]

[30] Section B of the appendix examines a setting where firms search for good news about applicants, and analogously finds that prices are excessively high and information-acquisition levels are too low in equilibrium. This inefficiency occurs because firms do not account for the consumer surplus earned by low-cost applicants who are mistakenly rejected. Again, there is a divergence between the social and private benefit of information acquisition. Section C presents a framework in which the type of search is endogenously determined, and the results are also analogous.

Economic discrimination was investigated in a setting with two groups of consumers, a high-risk group and a low-risk group. In the absence of regulation, members of the high-risk group face a higher equilibrium price than members of the low-risk group. Banning price discrimination accentuates quantity discrimination by leading to a situation in which high-risk applicants are subjected to more scrutiny and suffer disproportionately high rejection rates, although their overall welfare rises.

Finally, a setting in which rejected applicants remain in the market and apply to firms unaware of their earlier rejections was considered. The resulting adverse selection was shown to be potentially very severe, either causing the market to shut down or to generate a situation in which information acquisition is largely wasteful.

There are, of course, many aspects of the lending process that were not considered here: underwriting by third-party brokers who work separately from lenders; the impact of securitization; and varying levels of sophistication among consumers, in terms of both their knowledge of their qualifications and of how loans are priced, to name a few. The lending process is complex and it is probably not possible to capture all of its facets in a single model, and no attempt was made to do so here. Rather, this investigation was focused on a single – but important – aspect of mortgage lending, the incentive for acquiring information about applicants in a competitive mortgage industry. A multitude of other important issues awaits future work.

Appendix

This appendix contains the proofs of all results presented in the text as well as two additional variations of our base setup.

A Proofs

Lemma 1

Proof. Suppose that (3) holds and substitute from (4) into $W(n)$ to obtain the welfare from implementing Policy 1

$$W^* = -m + (1-\lambda)(v - c_L) + m \ln\left(\frac{m}{\lambda(c_H - v)}\right). \tag{A1}$$

Differentiating this with respect to m yields

$$\frac{\partial W^*}{\partial m} = \ln\left(\frac{m}{\lambda(c_H - v)}\right).$$

This is strictly negative for $m \in (0, \lambda(c_H - v))$. Moreover, evaluating W^* at $m = \lambda(c_H - v)$ reveals

$$W^* = v - \lambda c_H - (1-\lambda)c_L.$$

This is obviously non-positive if and only if the market is not *ex ante* viable. Moreover,

$$\lim_{m \to 0} W^* = (1-\lambda)(v - c_L) > 0.$$

Hence, W^*, which is continuous in m, is positive at $m = 0$, decreases monotonically, and is non-positive at $m = \lambda(c_H - v)$. ■

Proposition 1

Proof. Each part is proven in turn:

(i) First, suppose that the market is *ex ante* viable and (3) holds. It was shown in the text that if (3) holds, then Policy 1 strictly dominates Policy 2. Moreover, the welfare from implementing Policy 2 is $v - \lambda c_H - (1-\lambda)c_L$, which is positive. Hence, Policy 2 dominates Policy 3.

Next, suppose that the market is not *ex ante* viable and $m < m^\dagger$. Since the market is not *ex ante* viable, Policy 3 dominates Policy 2. However, by Lemma 1, $W^* > 0$, so Policy 1 dominates Policy 3.

(ii) Suppose that the market is *ex ante* viable and (3) fails. It was shown in the text that if (3) fails, then Policy 2 dominates Policy 1. Moreover, the welfare from implementing Policy 2 is $v - \lambda c_H - (1-\lambda)c_L$, which is positive. Hence, Policy 2 dominates Policy 3 in this case.

(iii) Suppose that the market is not *ex ante* viable and $m \geq m^\dagger$. The welfare from implementing Policy 2 is $v - \lambda c_H - (1-\lambda)c_L$, which is non-positive. Hence, Policy 3 dominates Policy 2. Moreover, Lemma 1 indicates that $W^* \leq 0$, so Policy 3 dominates Policy 1 as well.

■

Lemma 2

Proof. Suppose that $p < p^\dagger$ and substitute from (6) into (A2) to get

$$U(p, \overline{n}(p)) = \left(\frac{m}{c_H - p} + (1 - \lambda) \right) (v - p). \tag{A2}$$

Differentiation yields

$$\frac{dU(p, \overline{n}(p))}{dp} = \frac{m(v - c_H)}{(c_H - p)^2} - (1 - \lambda).$$

This is negative because $c_H > v$. For $p \geq p^\dagger$, $U(p) = v - p$, which is obviously decreasing. ■

Lemma 3

Proof. First, suppose that the market is not *ex ante* viable and $m \geq m^\dagger$. By way of contradiction, suppose that the set of relevant prices is non-empty. By Proposition 1, it is efficient to abandon the market and obtain first-best welfare of zero. If a firm alone sets the lowest relevant price p, then all the consumers apply to it and earn aggregate consumer surplus of

$$U(p, \overline{n}(p)) = \left(\lambda(1 - \alpha)^{\overline{n}(p)} + (1 - \lambda) \right) (v - p) > 0.$$

The total surplus earned in the market cannot exceed first-best welfare. Hence,

$$U(p, \overline{n}(p)) + \Pi(p, \overline{n}(p)) \leq 0.$$

It follows, therefore, that $\Pi(p, \overline{n}(p)) < 0$, which contradicts the supposition.

Next, suppose that the market is *ex ante* viable or that $m < m^\dagger$. Applying the Envelope Theorem to (8) gives

$$\frac{\partial \Pi(p, \overline{n}(p))}{\partial p} = \lambda(1 - \alpha)^{\overline{n}(p)} + (1 - \lambda) > 0.$$

Also,

$$\Pi(c_L, \overline{n}(c_L)) = \lambda(1 - \alpha)^{\overline{n}(c_L)}(c_L - c_H) - k\overline{n}(c_L) < 0.$$

Hence, $\Pi(p, \overline{n}(p))$ is strictly increasing and negative at $p = c_L$. Since it is evidently continuous, the result follows from observing that $\Pi(v, n) = W(n)$ and $W(n^*) > 0$. ■

Proposition 2

Proof. For cases (i) and (ii), Lemma 3 reveals that there is a unique zero-profit price $\overline{p} < v$. Standard Bertrand-style arguments (see Tirole (1988) pp. 209–11) then establish that in any equilibrium at least two firms post a price of $\overline{p}$ and no firm posts a lower price, and such a constellation of prices is an equilibrium. Consumers apply to the low price firms by Lemma 2. Firms acquire information according to (6).

For case (iii) observe that the set of relevant prices is empty. In other words, there exists no price that yields applicants positive expected utility in the continuation equilibrium. ■

Lemma 4

Proof. Differentiate (1) to get

$$AC'(n) = \frac{\lambda \ln(1-\alpha)(1-\alpha)^n((1-\lambda)(c_H - c_L) - kn) + k(\lambda(1-\alpha)^n + (1-\lambda))}{(\lambda(1-\alpha)^n + (1-\lambda))^2}. \tag{A3}$$

Evaluating this at $n = 0$ gives

$$AC'(0) = -\ln(1-\alpha)(m - \lambda(1-\lambda)(c_H - c_L)).$$

This is obviously negative when $m < \lambda(1-\lambda)(c_H - c_L)$. Suppose, therefore, that the market is not *ex ante* viable but that $m < m^\dagger$. Because the market is not *ex ante* viable and because $0 < m^\dagger < \lambda(c_H - v)$, it follows that

$$(1-\lambda)(v - \lambda c_H - (1-\lambda)c_L) + m^\dagger \ln\left(\frac{m^\dagger}{\lambda(c_H - v)}\right) < 0.$$

Rearranging this gives

$$(1-\lambda)(v - c_L) + m^\dagger \ln\left(\frac{m^\dagger}{\lambda(c_H - v)}\right) - \lambda(1-\lambda)(c_H - c_L) < 0.$$

Substituting for the first two terms from the definition of $m^\dagger$ (i.e., set the right side of (A1) equal to zero) gives

$$m^\dagger - \lambda(1-\lambda)(c_H - c_L) < 0.$$

Since $m < m^\dagger$ it follows that $AC'(0) < 0$. Hence, $AC(n)$ is initially decreasing. Moreover,

$$\lim_{n\to\infty} AC(n) = +\infty.$$

So, AC attains a global minimum at some critical point in $\mathbb{R}_+$ where $AC' = 0$.

Next, rewrite (A3) in the form

$$AC'(n) = \left(\frac{\lambda \ln(1-\alpha)(1-\alpha)^n}{(\lambda(1-\alpha)^n + (1-\lambda))^2}\right)\left((1-\lambda)(c_H - c_L) - kn - m\left(1 + \frac{(1-\lambda)}{\lambda(1-\alpha)^n}\right)\right). \tag{A4}$$

The first term is evidently negative. Hence, the second term must equal zero at a critical point. Moreover, at any critical point, the sign of AC'' must equal the sign of

$$\frac{d}{dn}\left(kn + m\frac{(1-\lambda)}{\lambda(1-\alpha)^n}\right) = k + k\left(\frac{(1-\lambda)}{\lambda(1-\alpha)^n}\right),$$

which is positive. Hence, there is a single critical point, $\tilde{n}$, at which $AC'(\tilde{n}) = 0$, and it corresponds to the global minimum of AC.

Finally, set the second term in (A4) equal to zero and multiply through by

$$-\frac{\lambda(1-\alpha)^{\tilde{n}}}{\lambda(1-\alpha)^{\tilde{n}} + (1-\lambda)}$$

to get

$$m - \lambda(1-\alpha)^{\tilde{n}}\left(\frac{(1-\lambda)(c_H - c_L) - k\tilde{n}}{\lambda(1-\alpha)^{\tilde{n}} + (1-\lambda)}\right) = 0,$$

or

$$m - \lambda(1-\alpha)^{\tilde{n}} \left(c_H - \frac{\lambda(1-\alpha)^{\tilde{n}} c_H + (1-\lambda)c_L + k\tilde{n}}{\lambda(1-\alpha)^{\tilde{n}} + (1-\lambda)} \right) = 0,$$

or

$$\lambda(1-\alpha)^{\tilde{n}}(c_H - AC(\tilde{n})) = m.$$

Since firms earn zero profit in equilibrium we have that $\overline{p} = AC(\overline{n}(\overline{p}))$. Substituting into (6) gives

$$\lambda(1-\alpha)^{\overline{n}(\overline{p})}(c_H - AC(\overline{n}(\overline{p}))) = m.$$

Hence, $\overline{n}(\overline{p}) = \tilde{n}$. ∎

Proposition 3

Proof. First, suppose the market is *ex ante* viable and $\lambda(c_H - v) \leq m < \lambda(1-\lambda)(c_H - c_L)$. Then $\overline{n}(\overline{p}) > 0$ by Lemma 4, while $n^* = 0$ by Proposition 1.

Next, suppose either that the market is *ex ante* viable and $m < \lambda(v - c_H)$ or that the market is not *ex ante* viable and $m < m^{\dagger}$. Then, the efficient level of information acquisition is given in (4) and the equilibrium level is given in (6). Comparing these equations reveals $\overline{n}(v) = n^*$. By Lemma 3, $\overline{p} < v$. The result then follows from the fact that $\overline{n}(p)$ is strictly decreasing. ∎

Proposition 4

Proof. If the market is *ex ante* viable and information acquisition is prohibited, then Bertrand competition will clearly result in equilibrium welfare of $v - \lambda c_H - (1-\lambda)c_L$.

(i) Suppose $m \in [\lambda(c_H - v), \lambda(1-\lambda)(c_H - c_L))$. In this case, Proposition 2 indicates that a Type 1 equilibrium with $\overline{n}(\overline{p}) > 0$ will prevail. Observe, however, that Proposition 1 indicates that Policy 2 (acquire no information and allocate the good to all consumers) is socially optimal.

(ii) The welfare deriving from a Type 1 equilibrium is

$$\overline{W} \equiv \left(\lambda(1-\alpha)^{\overline{n}(\overline{p})} + (1-\lambda) \right) (v - \overline{p}).$$

Substituting from (6) renders this as

$$\overline{W} \equiv \left(\frac{m}{c_H - \overline{p}} + (1-\lambda) \right) (v - \overline{p}).$$

Observe that

$$\lim_{m \to 0} \overline{W} = (1-\lambda)(v - c_L) > v - \lambda c_H - (1-\lambda)c_L.$$

Since $\overline{W}$ is evidently continuous in m, this establishes the claim.

∎

Lemma 5

Proof. For a general value of λ, the price in a Type 1 equilibrium is found by substituting (6) into the zero-profit condition

$$\Pi(\overline{p}, \overline{n}(\overline{p})) = -m + (1-\lambda)(\overline{p} - c_L) + m \ln\left(\frac{m}{\lambda(c_H - \overline{p})}\right) = 0. \tag{A5}$$

Implicit differentiation yields

$$\frac{\partial \overline{p}}{\partial \lambda} = \frac{(c_H - \overline{p})\left(\lambda(\overline{p} - c_L) + m\right)}{\lambda\left((1-\lambda)(c_H - \overline{p}) + m\right)} > 0. \tag{A6}$$

Hence, $\lambda_H > \lambda_L$ implies $\overline{p}_H > \overline{p}_L$. Next, differentiate (A2) with respect to λ to get

$$\frac{\partial U(\overline{p}, \overline{n}(\overline{p}))}{\partial \lambda} = -(v - \overline{p}) + \frac{dU(\overline{p}, \overline{n}(\overline{p}))}{d\overline{p}} \frac{\partial \overline{p}}{\partial \lambda}.$$

This is negative by Lemma 2 and (A6). ∎

Proposition 5

Proof. Lemma 5 reveals $\overline{p}_L < \overline{p}_H$. Hence, the result will follow from (6) and from Lemma 2 if it can be shown that $\overline{p}_M \in (\overline{p}_L, \overline{p}_H)$. Expected equilibrium profit to a typical firm is

$$\begin{aligned}&\theta\left(\lambda_H(1-\alpha)^{\overline{n}_H}(\overline{p}_M - c_H) + (1-\lambda_H)(\overline{p}_M - c_L) - k\overline{n}_H\right) \\ &+(1-\theta)\left(\lambda_L(1-\alpha)^{\overline{n}_L}(\overline{p}_M - c_H) + (1-\lambda_L)(\overline{p}_M - c_L) - k\overline{n}_L\right).\end{aligned}$$

Substituting for $\overline{n}_H$ and $\overline{n}_L$ from (6) and setting profit equal to zero implicitly defines the equilibrium price

$$\begin{aligned}&\theta\left[-m + (1-\lambda_H)(\overline{p}_M - c_L) + m\ln\left(\tfrac{m}{\lambda_H(c_H - \overline{p}_M)}\right)\right] \\ &+(1-\theta)\left[-m + (1-\lambda_L)(\overline{p}_M - c_L) + m\ln\left(\tfrac{m}{\lambda_L(c_H - \overline{p}_M)}\right)\right] = 0.\end{aligned}$$

Both terms in square brackets are evidently increasing in $\overline{p}_M$. Moreover, the first term is zero when $\overline{p}_M = \overline{p}_H$ and the second term is zero when $\overline{p}_M = \overline{p}_L$. Hence, the average of the two terms is zero only if $\overline{p}_M \in (\overline{p}_L, \overline{p}_H)$. ∎

Proposition 6

Proof. By definition

$$\gamma(p) = \begin{cases} -m + (1-\mu(p,\psi))(p - c_L) + m\ln\left(\frac{m}{\mu(p,\psi)(c_H - p)}\right), & \text{if } p < p^\dagger \\ p - \lambda c_H - (1-\lambda)c_L, & \text{if } p \geq p^\dagger. \end{cases} \qquad p \in [c_L, c_H].$$

First, observe that $\gamma(p)$ is continuous. In particular,

$$-m + (1-\lambda)(p^\dagger - c_L) + m\ln\left(\frac{m}{\lambda(c_H - p^\dagger)}\right) = p^\dagger - \lambda c_H - (1-\lambda)c_L.$$

Next, observe that $\gamma(p)$ is clearly increasing for $p \geq p^\dagger$. For $p < p^\dagger$,

$$\gamma'(p) = (1-\mu(p,\psi)) - \mu_p(p,\psi)(p - c_L) + m\left(\frac{1}{c_H - p} - \frac{\mu_p(p,\psi)}{\mu(p,\psi)}\right).$$

This is positive because

$$\mu_p(p, \psi) = -\frac{(1-\lambda)\psi m}{(1-(1-\lambda)\psi)(c_H - p)^2} \leq 0.$$

Hence, there exists at most one value $\hat{p} \in [c_L, c_H]$ for which $\gamma(\hat{p}) = 0$. Moreover, if such a $\hat{p}$ exists, then $v > \hat{p}$ *iff* $\gamma(v) > 0$.

Suppose $m < \lambda(1-\lambda)(c_H - c_L)$. Then $c_L < p^\dagger$. Substitution yields

$$\gamma(c_L) = -m + m \ln\left(\frac{m}{\mu(c_L, \psi)(c_H - c_L)}\right).$$

To see that this is negative, observe that

$$m < \lambda(1-\lambda)(c_L - c_H) \;\Leftrightarrow\; \lambda < \mu(c_L, \psi).$$

And hence

$$m < \lambda(1-\lambda)(c_H - c_L) < \lambda(c_H - c_L) < \mu(c_L, \psi)(c_H - c_L).$$

Next, observe that

$$\gamma(p^\dagger) = (1-\lambda)(c_H - c_L) - \frac{m}{\lambda}.$$

This is clearly positive *iff* $m < \lambda(1-\lambda)(c_H - c_L)$. Hence, there exists a unique steady-state equilibrium price $\hat{p} \in (c_L, p^\dagger)$, and it gives rise to positive screening and adverse selection.

Finally, assume $m \geq \lambda(1-\lambda)(c_H - c_L)$. There are two cases to consider. First, if $p^\dagger \geq c_L$, then the above argument establishes that $\gamma(p^\dagger) \leq 0$. On the other hand, if $p^\dagger < c_L$, then

$$\gamma(c_L) = \lambda(c_L - c_H) < 0.$$

In either case,

$$\gamma(c_H) = (1-\lambda)(c_H - c_L) > 0.$$

Hence, there exists a unique steady-state equilibrium price $\hat{p} \in (c_L, c_H)$, and the fact that $\hat{p} > p^\dagger$ implies that the equilibrium involves no screening ($\hat{\phi} = 0$) and no adverse selection ($\hat{\mu} = \lambda$). ■

Proposition 7

Proof. If $\psi = 0$, then (12) reveals that $\hat{\mu} = \lambda$. The claim then follows from the zero-profit condition (10) and the first-order condition (9).

Next, suppose $m < \lambda(1-\lambda)(c_H - c_L)$. In this case, Proposition 6 shows that $\hat{p} < p^\dagger$. This implies that the zero-profit condition (10) can be written

$$\pi = -m + (1-\hat{\mu})(\hat{p} - c_L) + m \ln\left(\frac{m}{\hat{\mu}(c_H - \hat{p})}\right) = 0$$

and (12) can be written

$$\hat{\mu} = \mu(\hat{p}, \psi).$$

Differentiating these with respect to ψ yields respectively

$$\pi_p \frac{\partial \hat{p}}{\partial \psi} + \pi_\mu \frac{\partial \hat{\mu}}{\partial \psi} = 0$$

and

$$\frac{\partial \hat{\mu}}{\partial \psi} = \mu_p \frac{\partial \hat{p}}{\partial \psi} + \mu_\psi.$$

Solving these gives

$$\frac{\partial \hat{p}}{\partial \psi} = -\frac{\pi_\mu \mu_\psi}{\pi_p + \pi_\mu \mu_p}$$

and

$$\frac{\partial \hat{\mu}}{\partial \psi} = \frac{\mu_\psi \pi_p}{\pi_p + \pi_\mu \mu_p}.$$

These are both positive because

$$\pi_p = (1 - \hat{\mu}) + \frac{m}{c_H - \hat{p}} > 0,$$

$$\pi_\mu = -(\hat{p} - c_L) - \frac{m}{\hat{\mu}} < 0,$$

$$\mu_p = -\frac{(1-\lambda)\psi m}{(1-(1-\lambda)\psi)(c_H - \hat{p})^2} < 0,$$

and

$$\mu_\psi = \frac{(1-\lambda)(\lambda(c_H - \hat{p}) - m)}{(1-(1-\lambda)\psi)^2(c_H - \hat{p})} > 0.$$

Finally,

$$\hat{\phi} = 1 - \frac{m}{\hat{\mu}(c_H - \hat{p})}.$$

Hence,

$$\frac{\partial \hat{\phi}}{\partial \psi} > 0$$

iff

$$\frac{m}{(\hat{\mu}(c_H - \hat{p}))^2} \left((c_H - \hat{p}) \frac{\partial \hat{\mu}}{\partial \psi} - \hat{\mu} \frac{\partial \hat{p}}{\partial \psi} \right) > 0,$$

or

$$(c_H - \hat{p}) \frac{\partial \hat{\mu}}{\partial \psi} - \hat{\mu} \frac{\partial \hat{p}}{\partial \psi} > 0,$$

or

$$(c_H - \hat{p})\pi_p + \hat{\mu}\pi_\mu > 0,$$

or

$$\hat{p} - \hat{\mu} c_H - (1 - \hat{\mu}) c_L < 0.$$

The last line holds because a firm could otherwise make non-negative profit by pricing at $\hat{p}$ and selling the good without screening, contrary to Proposition 6. ■

B Searching for Good News

In this section, a variant of the model is studied in which firms have access to a different type of information acquisition technology. Specifically, prior to this point it has been assumed that firms search for 'bad news' in the sense that a single negative piece of information (e.g., a criminal conviction) reveals an applicant to be type c_H with certainty. Suppose to the contrary that a single piece of 'good news' (e.g., a positive reference) reveals an applicant to be type c_L. That is, consider n conditionally independent Bernoulli signals, $Y_1, \ldots, Y_n$, where

$$\Pr\{Y_i = 1|c\} = \begin{cases} \alpha, & \text{if } c = c_L, \\ 0, & \text{if } c = c_H \end{cases}$$

This information structure corresponds to searching for good news in the sense that it admits no false positives. Hence, firms collect information on their applicants and approve them if and only if they observe at least one favorable signal ($Y_i = 1$).

The expected payoff to an applicant in this setting is

$$\widetilde{U}(p, n) \equiv (1-\lambda)\left(1-(1-\alpha)^n\right)(v-p). \tag{G1}$$

As before, the first term in this expression is the probability of having his application approved and the second term is the surplus from purchasing the good. The cost to a firm per accepted application is

$$\widetilde{AC}(n) = c_L + \frac{kn}{(1-\lambda)\left(1-(1-\alpha)^n\right)}.$$

When m is sufficiently small, the socially efficient search intensity is characterized by the first-order condition

$$(1-\lambda)(1-\alpha)^{n^{**}}(v-c_L) = m.$$

It is useful to compare this with the condition defining the optimal sample size when searching for bad news, (4). When searching for bad news, the marginal social benefit of information acquisition derives from identifying a type c_H applicant and denying him the product (saving surplus of $c_H - v$). When searching for good news, by contrast, the marginal social benefit of information acquisition derives from identifying a type c_L applicant and allocating him the product (generating surplus of $v - c_L$).

A firm that posts price p selects its search intensity, $\tilde{n}(p)$, according to the first-order condition

$$(1-\lambda)(1-\alpha)^{\tilde{n}(p)}(p-c_L) = m. \tag{G2}$$

Proposition 8 (Insufficient Information Acquisition)**.** *The unique equilibrium outcome when firms search for good news involves positive information acquisition* iff *the market is* ex ante *viable and* $m < \lambda(1-\lambda)(c_H - c_L)$*, or the market is not* ex ante *viable and* $m < (1-\lambda)(v-c_L)$*. The equilibrium price is*

$$\tilde{p} = c_L + \sqrt{\frac{m(v-c_L)}{1-\lambda}}.$$

Moreover, $\tilde{n}(\tilde{p}) < n^{**}$ *(i.e., firms acquire too little information about their applicants).*

Proof. The result is proven in three steps.

Step 1. Substitute from (G2) into (G1) to get

$$\widetilde{U}(p,\tilde{n}(p)) = \left((1-\lambda) - \frac{m}{p-c_L}\right)(v-p).$$

Differentiation yields

$$\frac{d\widetilde{U}(p,\tilde{n}(p))}{dp} = \frac{m(v-c_L)}{(p-c_L)^2} - (1-\lambda)$$

and

$$\frac{d^2\widetilde{U}(p,\tilde{n}(p))}{(dp)^2} = -\frac{2m(v-c_L)}{(p-c_L)^3} < 0.$$

Hence, $\widetilde{U}(p,\tilde{n}(p))$ is maximized at $\tilde{p}$.

Step 2. Suppose the market is *ex ante* viable. For $m \geq \lambda(1-\lambda)(c_H - c_L)$, the equilibrium outcome evidently involves pricing at $p^0 = \lambda c_H + (1-\lambda)c_L$ and accepting all applications. Next, suppose $m < \lambda(1-\lambda)(c_H - c_L)$. By Step 1, the unique equilibrium outcome will involve all firms pricing at $\tilde{p}$ and acquiring information optimally if

$$\tilde{p} < v \Leftrightarrow m < (1-\lambda)(v-c_L).$$

Simple algebra reveals

$$v > \lambda c_H + (1-\lambda)c_L \Leftrightarrow (1-\lambda)(v-c_L) > \lambda(1-\lambda)(c_H-c_L),$$

from which the result follows.

Step 3. Suppose the market is not *ex ante* viable. For $m \geq (1-\lambda)(v-c_L)$, no equilibrium in which the market is active exists. Specifically, if firms price less than v and acquire no information, then they will clearly reject all applications. To see that no equilibrium with positive information acquisition exists either, note from (G2) that a firm will acquire information about an applicant *iff*

$$p > c_L + \frac{m}{1-\lambda}.$$

But

$$c_L + \frac{m}{1-\lambda} \geq v.$$

Hence, consumers will not apply to purchase the good at any price that induces positive information acquisition. Now consider $m < (1-\lambda)(v-c_L)$. Simple algebra shows that this condition is equivalent to $\tilde{p} < v$. Hence, it remains only to show that firms make non-negative profit by pricing at $\tilde{p}$ and approving qualified applicants. The profit per applicant from this strategy is

$$\begin{aligned}\widetilde{\Pi} &= \left(1-(1-\alpha)^{\tilde{n}(\tilde{p})}\right)(\tilde{p}-c_L) - k\tilde{n}(\tilde{p}) \\ &= \sqrt{m(1-\lambda)(v-c_L)} - m + m\ln\left(\sqrt{m/((1-\lambda)(v-c_L))}\right) \\ &= m\left(z^{-1} - 1 + \ln(z)\right),\end{aligned}$$

where

$$z = \sqrt{\frac{m}{(1-\lambda)(v-c_L)}}.$$

Note that $z = 1$ implies $\widetilde{\Pi} = 0$. Moreover,

$$\frac{d}{dz}\left(z^{-1} - 1 + \ln(z)\right) = z^{-1} - z^{-2}.$$

This is evidently negative *iff* $z < 1$. Hence, $m \in (0, (1-\lambda)(v - c_L))$ implies $\widetilde{\Pi} > 0$. At $m = 0$, the equilibrium involves perfect information; i.e., firms screen all applicants at zero cost and set the competitive price of c_L.

■

Proposition 3 of Section 5 shows that if firms search for bad news about their applicants, then they collect too much information in equilibrium. By contrast, Proposition 8 shows that if firms search for good news, then they collect too little information. The upshot in either case is that too few applicants are approved.

The reason firms collect too little information when searching for good news is easily understood. As noted above, mistakes in this environment involve not identifying some of the low-cost consumers. The social cost of each mistake is, therefore, $v - c_L$. The private cost to a firm, however, is $\tilde{p} - c_L$. Since $\tilde{p} < v$, the private cost of making a mistake is smaller than the social cost and firms, therefore, acquire too little information.

An interesting feature of the equilibrium outcome characterized in Proposition 8 is that firms earn strictly positive profit. The reason competition fails in this setting is easily explained. When firms search for good news, a consumer's expected utility in the continuation equilibrium, $\widetilde{U}(p, \tilde{n}(p))$, is not monotone decreasing. In particular, it is increasing for prices less than $\tilde{p}$ and decreasing for higher prices. Hence, a firm setting a price less than $\tilde{p}$ will attract no applicants. Low prices induce low levels of information acquisition and, therefore, result in very low probability of acceptance.

C Endogenous Search

Consider an alternative information technology where rather than searching for 'good news' or 'bad news', a firm chooses a probability α with which it receives an informative signal at cost $c(\alpha) = \alpha^2$. Specifically, suppose that if a firm chooses to acquire information about an applicant it receives a signal s;

$$s = \begin{cases} c & \text{with probability } \alpha \\ \emptyset & \text{with probability 1-}\alpha \end{cases}$$

where c denotes the applicant's type. Thus, with probability α the firm receives a perfectly informative signal, learning whether or not the applicant is qualified, and with probability $1 - \alpha$ the firm receives an empty signal and is left with the common prior.[31] For simplicity and to ensure an interior solution, we further suppose $1 > c_H > v > c_L \geq 0$. All other aspects of the basic set up remain unchanged.

[31] It is straightforward to verify that the results would continue to hold if information was not perfect, but sufficiently informative.

As in the main text, we proceed by deriving the first-best solution and comparing it to the market equilibrium.

First-Best Solution

Suppose a social planner, interested in maximizing the expected utility of consumers, operates the firms subject to a zero-profit constraint. Notice that given the information technology, either the social planner receives a signal revealing the applicant's type and will allocate the good accordingly, or she receives an empty signal and must decide how to proceed.[32] Following an uninformative signal, the social planner will allocate the good if the (*ex ante*) expected benefit to doing so exceeds the (*ex ante*) expected cost, i.e. if the market is *ex ante* viable:

$$v > \lambda c_H + (1-\lambda)c_L.$$

Suppose initially that the market is *ex ante* viable. Given that she will allocate the good conditional on an uninformative signal, the social planner solves the following problem (where the v subscript denotes *ex ante* viability):

$$\max_{(p_v,\alpha_v)} U(p_v,\alpha_v) \equiv ((1-\lambda)+\lambda(1-\alpha_v))(v-p_v) \quad \text{s.t. } p_v = AC(\alpha_v), \tag{R1}$$

where

$$AC(\alpha_v) = \frac{(1-\lambda)c_L + \lambda(1-\alpha)c_H + \alpha_v^2}{1-\lambda+\lambda(1-\alpha_v)}. \tag{R2}$$

With probability $1-\lambda$, the application has come from a low-cost type in which case the firm will allocate the good with certainty. With probability λ, the application has come from a high-cost type and the good will be allocated only if the firm's search is uninformative, which occurs with probability $1-\alpha_v$. When the good is allocated, the net social surplus is given by $(v-p_v)$ where p_v is defined by R2.

Solving the above yields

$$\alpha_v^* = \frac{\lambda(c_H - v)}{2}$$
$$p_v^* = AC(\alpha_v^*).$$

If the market is not *ex-ante* viable, then the social planner will reject applications following an empty signal and will only accept applicants revealed to be the low-cost type. Thus, she solves the following maximization problem:

$$\max_{(p_{nv},\alpha_{nv})} U(p_{nv},\alpha_{nv}) \equiv (1-\lambda)\alpha_{nv}(v-p_{nv}) \quad \text{s.t. } p_{nv} = AC(\alpha_{nv}), \tag{R3}$$

where

$$AC(\alpha_{nv}) = \frac{(1-\lambda)\alpha_{nv}c_L + \alpha_{nv}^2}{(1-\lambda)\alpha_{nv}}. \tag{R4}$$

[32]Notice the social planner will gather some information as the marginal cost of information at $\alpha = 0$ is zero, while the marginal benefit to information acquisition is strictly positive.

Solving the above yields

$$\alpha_{nv}^{*} = \frac{(1-\lambda)(v-c_L)}{2}$$

$$p_{nv}^{*} = AC(\alpha_{nv}^{*}) = \frac{v+c_L}{2}.$$

Notice that if the market is *ex-ante* viable, the social planner is effectively searching for 'bad news'. She allocates the good unless she receives a signal indicating the applicant is a high-cost type. Conversely, if the market is not *ex-ante* viable, the social planner searches for 'good news'. She allocates the good only if she receives a signal indicating the applicant is a low-cost type. Rather than having two disparate search technologies, the type of search conducted by the social planner is determined endogenously by the proportion of cost types.

Comparing across the two scenarios reveals:

$$p_v^{*} > p_{nv}^{*}$$

and

$$1 - \lambda\alpha_v^{*} > (1-\lambda)\alpha_{nv}^{*}$$

When the market is *ex ante* viable, consumers face higher prices, but also receive the good with higher probability. This makes sense. A consumer's valuation is large relative to the *ex ante* expected cost of providing the good when the market is viable, so the social planner will err towards provision and provide the good following an uninformative search. Since the good will occasionally be misallocated to a high cost type, consumers must face a higher price to ensure firms receive non-negative profits.

Market Equilibrium

As in the main text, suppose there are at least two identical risk-neutral profit maximizing firms. Following an informative search, a firm will clearly allocate the good to an applicant revealed to be a low-cost type and reject an applicant revealed to be a high-cost type. However, rather than *ex ante* viability determining whether the good is allocated following an empty signal, a firm will approve an application if the price charged in the first stage exceeds the expected cost of providing the good, i.e., if:

$$p_j \geq \lambda c_H + (1-\lambda)c_L. \tag{R5}$$

(R5) is the analogous condition to market viability in the social planner's problem. If the price set in the first stage of the game satisfies (R5), the firm will allocate the good following an uninformative search. Therefore, under this condition the firm faces the following maximization problem:

$$\max_{\alpha_v^F}(1-\lambda)(p_j - c_L) + \lambda(1-\alpha_v^F)(p_j - c_H) - (\alpha_v^F)^2$$

where the F superscript indicates the firm's (as opposed to the social planner's) decision. Solving the above yields:

$$\alpha_v^F(p_j) = \frac{\lambda(c_H - p_j)}{2}.$$

As in the main text, the amount of search a firm conducts is unobservable and unverifiable, so firms compete solely on the basis of price. Consumers, therefore, will apply to whichever firm posts the most attractive price in the first stage. A consumer's expected utility from applying to a firm posting price p_j is simply the probability his application is approved multiplied by his surplus from being allocated the good, or:

$$U(p_j, \alpha_v^F(p_j)) = (1 - \lambda\alpha_v^F(p_j))(v - p_j). \tag{R6}$$

It is straightforward to verify that

$$\frac{\partial U(p_j, \alpha_v^F(p_j))}{\partial p_j} < 0. \tag{R7}$$

Decreasing the price a firm charges increases the intensity with which applications are screened, thereby decreasing the chance an applicant is allocated the good. However, the indirect cost of a lower probability of being approved is outweighed by the direct benefit of facing a lower price conditional on acceptance.

In light of the above, a firm will set the lowest possible price consistent with (R5), i.e.

$$p_v^F = \lambda c_H + (1 - \lambda)c_L,$$

implying

$$\alpha_v^F = \frac{\lambda(1 - \lambda)(c_H - c_L)}{2}.$$

If the price set in the first stage does not satisfy (R5), then a firm will allocate the good only if the applicant is revealed to be a low-cost type. Under this condition, the firm faces the following maximization problem:

$$\max_{\alpha_{nv}^F}(1 - \lambda)\alpha_{nv}^F(p_j - c_L) - (\alpha_{nv}^F)^2$$

Solving this optimization problem yields:

$$\alpha_{nv}^F(p_j) = \frac{(1 - \lambda)(p_j - c_L)}{2}$$

As before, a consumer will apply to whichever firm posts the most attractive price. When the price set in the first stage does not satisfy (R5), a consumer's expected utility is given by:

$$U(p_j, \alpha_{nv}^F(p_j)) = (1 - \lambda)\alpha_{nv}^F(p_j)(v - p_j). \tag{R8}$$

Differentiating with respect to p_j reveals that expected utility is non-monotonic in price and is maximized when:

$$p_{nv}^F = \frac{v + c_L}{2},$$

implying

$$\alpha_{nv}^F = \frac{(1 - \lambda)(v - c_L)}{4}.$$

It is straightforward to show that under (R5), consumers face higher prices, but also receive the good with higher probability. It remains to be seen under what conditions applicants prefer this scenario.

Whether or not the price set in the first stage satisfies (R5), an applicant's expected utility from applying to a firm is the probability his application is accepted multiplied by the benefit of being allocated the good. Substituting for equilibrium prices and search intensities yields:

$$U_v = \left(1 - \frac{\lambda^2(1-\lambda)(c_H - c_L)}{2}\right)(v - \lambda c_H - (1-\lambda)c_L)$$

$$U_{nv} = \left(\frac{(1-\lambda)^2(v - c_L)}{4}\right)\left(v - \frac{v + c_L}{2}\right).$$

Notice that if the market is not *ex-ante* viable, i.e., $v < \lambda c_H + (1-\lambda)c_L$, consumers prefer the scenario in which there are lower prices but also a higher chance of rejection. Differencing expected utilities under the two scenarios and differentiating yields:

$$\frac{\partial(U_v - U_{nv})}{\partial v} = 1 - \frac{\lambda^2(1-\lambda)(c_H - c_L)}{2} - \frac{(1-\lambda)^2(v - c_L)}{4} > 0. \tag{R9}$$

Additionally, it is straightforward to verify that for valuations close to c_H, $U_v > U_{nv}$. Taken in combination, this implies

$$\exists \text{ a unique } v^* \in (\lambda c_H + (1-\lambda)c_L, c_H) \text{ such that } \forall v > v^*, U_v > U_{nv}, \tag{R10}$$

so that

$$\begin{cases} \text{If } v > v^* & U_v > U_{nv} \\ \text{If } v \leq v^* & U_{nv} \geq U_v. \end{cases}$$

The following proposition summarizes the preceding discussion.

Proposition 9 (Market Equilibrium)**.** *In the unique market equilibrium outcome,*

(i) *If $v > v^*$, at least two firms post the price $p^* = p_v^F$; consumers apply to the firms posting price p^*; firms posting price p^* acquire information according to $\alpha^* = \alpha_v^F$ and sell to all consumers not revealed to be the high-cost types.*

(ii) *If $v \leq v^*$, at least two firms post the price $p^* = p_{nv}^F$;[33] consumers apply to firms posting price p^*; firms posting price p^* acquire information according to $\alpha^* = \alpha_{nv}^F$ and sell only to consumers revealed to be the low-cost types.*

[33] *One can verify that $v^* < 2\lambda(c_H - c_L) + c_L$, ensuring that $p_{nv}^F < \lambda c_H + (1-\lambda)c_L$.*

Comparison of Market Equilibrium to the First-Best Solution

Having derived the market equilibrium outcomes and the outcomes under the first-best solution, we are now in a position to compare how consumers fare under the two regimes. Straightforward algebra reveals:

$$\begin{array}{lll}
\text{If } v > v^*, & \alpha_v^F > \alpha_v & p_v^F > p_v \\
\text{If } v < \lambda c_H + (1-\lambda)c_L & \alpha_{nv}^F < \alpha_{nv} & p_{nv}^F = p_{nv} \\
\text{If } v \in [\lambda c_H + (1-\lambda)c_L, v^*] & (1-\lambda)\alpha_{nv}^F < 1 - \lambda\alpha_v & p_{nv}^F < p_{nv}.
\end{array}$$

Notice that the distortions in the amount of information acquired resemble those found in the main text. When $v > v^*$, so that firms and the social planner are searching for 'bad news', firms acquire too much information and reject applicants too often. Conversely, when the market is not *ex-ante* viable, so that firms and the social planner are searching for 'good news', firms acquire too little information and again applicants are rejected too often. For intermediate valuations, there is also a distortion across regimes; the social planner searches for 'bad news' while the firms search for 'good news'. In all cases, applications are rejected too often in the market equilibrium.

Interestingly, however, the relationship between first-best and market prices differs from that in the main text. Under the information technology considered in this section, when firms search for 'bad news', they set prices inordinately high while in the main text prices are set inordinately low. When firms choose the probability with which they receive an informative signal, consumers would prefer lower prices when firms are searching for 'bad news', all else equal. However, if a firm posted a price lower than that in equilibrium, it would reject applications following an empty signal (effectively switching to searching for 'good news'), greatly decreasing the probability an application is accepted. There is no distortion in prices when firms search for 'good news' in this section. Under the information technology considered here, there is a linear relationship between prices and the amount of information acquired. Consumers care primarily about the first-order effects of distortions on prices and prefer to move all distortions to the amount of information acquired.

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