A SIGNALING-SCREENING EQULIBRIUM IN THEMORTGAGE MARKET

Danny Ben-Shahar* and David Feldman**

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Abstract

Screening equilibria, mainly those a la Rothchild-Stiglitz (1976), have been widely used to explain various aspects of mortgage contracting. In the real world, however, most mortgage contracting processes involve both signaling and screening. In this paper, we combine signaling and screening mechanisms to examine a mortgage selection process. Borrowers "buy" different credit histories, signaling their default risk type to lenders. Credit histories, however, are imperfect signals and only partially separate borrowers' risk types, clustering them into subsets. Then, lenders screen each subset by offering a different menu of mortgage loan contracts with varying pairs of interest rate and maturity. Borrowers, then, self-select by choosing a particular contract from the menu. In equilibrium, safer (riskier) borrowers maintain a better (worse) credit record and choose shorter (longer) maturity and lower (higher) risk premium mortgage loan contracts. We further show that the separating signaling-screening equilibrium is Pareto superior to a corresponding screening equilibrium.

*The Arison School of Business, The Interdisciplinary Center Herzliya; P.O. Box 167, Herzliya 46150, Israel; telephone: +972-9-952-7298, fax: 09-956-8605, email: danny@idc.ac.il

**Department of Business Administration, School of Management, Ben-Gurion University of the Negev, P.O. Box 653, Beer-Sheva 84105, ISRAEL and the Technion – Israel Institute of Technology, Faculty of Industrial Engineering and Management; telephone: +972-8-647-2106, fax 08-647-7691, email: feldmand@bgumail.bgu.ac.il

1 Introduction

Screening equilibria, mainly those a la Rothchild-Stiglitz (1976), have been widely used to explain various aspects of mortgage contracting. In the real world, however, most mortgage contracting processes involve both signaling and screening. In this paper, we combine signaling and screening mechanisms to examine a mortgage selection process. Borrowers “buy” different credit histories, signaling their default risk type to lenders. Credit histories, however, are imperfect signals and only partially separate borrowers’ risk types, clustering them into subsets. Then, lenders screen each subset by offering a different menu of mortgage loan contracts with varying pairs of interest rate and maturity. Borrowers, then, self-select by choosing a particular contract from the menu. In equilibrium, safer (riskier) borrowers maintain a better (worse) credit record and choose shorter (longer) maturity and lower (higher) risk premium mortgage loan contracts. We further show that the separating signaling-screening equilibrium is Pareto superior to a corresponding screening equilibrium.

Researchers in the seventies recognized that introducing asymmetric information might significantly alter the equilibrium. In particular, hidden actions might lead to moral hazard and hidden quality, or type, might lead to adverse selection. In his seminal work, Spence (1973a) identified separating equilibria, where agents of different types are rewarded as a function of (different) signals that they buy. Separation by signals implies separation by cost of signaling, which, in turn implies separation by the hidden attribute or quality. In another seminal work, Rothchild and Stiglitz (1976) identified a separating equilibrium, where agents of different types self-select using a menu of contracts.

Numerous studies followed, both methodological and applied. A very partial sample of methodological contributions includes Wilson (1977), Riley (1979), Engers

(1987), and Cho and Sobel (1988).[1] A very partial sample of applications includes Jaffee and Russell (1976), Leland and Pyle (1977), Grossman (1981), Reinganum and Wilde (1986), Admati and Perry (1987), and Milgrom and Roberts (1982).

One of the areas where screening models are extensively employed is the mortgage loan market. See, for example, Dunn and Spatt (1988), Brueckner (1992, 1994, and 2000), Stanton and Wallace (1998), and Posey and Yavas (2001).

In real world mortgage markets, however, we often observe the use of both signaling and screening in the mortgage loan selection process. In this paper, we model such equilibrium, explaining the mortgage selection mechanism and demonstrate that signaling and screening might coexist and complement one another.

In our model, borrowers signal their credit trustworthiness by "buying" a credit record. This signal, however, is imperfect and borrowers of several credit risk types might have identical credit records. Thus, by observing a signal in the form of a credit record, lenders merely learn the subset of risk types to which the borrower belongs. Lenders, then, screen borrowers by offering a different set of loan contracts to each subset, and borrowers self-select by choosing a particular contract.

In our mortgage market framework, loan contracts differ from one another in maturity and risk premium. Thus, lender, using borrowers' credit record signals, classify borrowers into subsets according to their default risk. Then, lenders offer a different menu of mortgage loans to each borrower subset, and borrowers by selecting loans from these menus fully separate themselves.

Intuitively, it is less costly for lower default risk types to acquire better credit records. Further, due to the relatively lower periodic payments (and in our equilibrium lower default probability) associated with longer maturity mortgages, borrowers with

[1] Additional related studies are, for example, Crawford and Sobel (1982), Wolinsky (1983), Quinzii

high probability of default, are more inclined to select longer maturity loan contracts. Hence, in equilibrium, lower default risk borrowers maintain better credit records and select shorter maturity mortgages. In return they pay lower risk premium.

Finally, we show the Pareto superiority of the signaling-screening equilibrium over the corresponding ordinary screening equilibrium. In the latter, only the riskiest borrower type in the entire population obtains its first best selection in equilibrium. Moreover, the safer the borrower type, the farther away it is from its first best choice. In the signaling-screening equilibrium, however, because borrowers are clustered into subsets, it is the riskiest borrower type *in each subset* that obtains its first best contract.

In section two, we construct the signaling-screening equilibrium and derive its implications. We summarize in section three.

2 The Model

Consider N types of borrowers of different liquidity levels (or liquidity) and liquidity processes. Borrower's $i,\ i ? 1,2,...,N,$ liquidity at time t, L_{it}, evolves as an Ornstein-Uhlenbeck type stochastic process that follows the stochastic differential equation,

(1)

$$dL_{it} ? ?_i(?_{it} ? L_{it})dt ? ?_i dW_{it},$$

where t represents time, with an initial condition L_{i0}. $\{W_{it},\ i ? 1,2,...,N,\ t ? 0\}$ is a Wiener process, with W_{i0}=0, where W_{it} is independent of W_{jt} $? i, j,\ i ? j$; $?_{it}$ is a deterministic function of time; and $?_i$, and $?_i$ are positive constants. At time t, borrower's i liquidity level, L_{it}, reverts to its instantaneous mean $?_{it}$, at a speed of adjustment $?_i$, with an instantaneous standard deviation $?_i$.

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and Rochet (1985), and Farrell (1988).

Borrowers' liquidity process represents the accumulation of their liquid wealth due to, for example, labor income, and capital gains and dividends from invested liquid wealth net of consumption. Current liquidity level and the liquidity process parameters ($?_{it}$, $?_i$, and $?_i$), determine the probability that future liquidity falls below a certain threshold, a situation we define as default. If the threshold is lower than both current liquidity and its current mean, then the default probability is decreasing in $?_{it}$, and $?_i$, and increasing in $?_i$. While we do not use these parameters explicitly in the rest of the model they provide some framework to the default phenomenon.

Borrowers face periodic mortgage loan payments. As long as their periodic liquidity level is above the level of the required payment, they continue to pay the loan. If the liquidity level falls below the level of the payment, borrowers choose to either default on the loan, or to liquidate fixed assets and meet loan requirements.

At the time borrowers sign a mortgage contract, their current "credit records" become observable to lenders. The realizations and parameters of borrowers' liquidity processes, however, are private information.

Consider a set of mortgage loan contracts. Each contract specifies the maturity of the loan and a periodic payment size per dollar borrowed. We assume that the payment size is determined both by the maturity of the loan and by a risk premium that compensates for the default risk of the borrower. For simplicity, we assume that the relevant term structure is such that the present value of all periodic payments is equal. We denote the maturity of the mortgage loan by t, (t? {1,2,…,T}), and the risk premium by r (r>0). Thus, a maturity-risk premium pair defines a payment size. Of course, the payment is decreasing in maturity, t, and increasing in risk premium, r. Different combinations of maturity and risk premium, however, might result in the same payment size. We model the present value of a single payment as $1/t+r$, which implies that the present value of the full loan repayment is $t(1/t+r)$.[2]

A mortgage loan contract experiences default, if the realization of the borrower’s liquidity process falls below the payment of the loan, after its inception and before it matures. The probability of default, $p(\cdot)$, is thus a function of maturity and risk premium, or $p=p(t,r)$. The greater the risk premium, the greater is each of the periodic payments, and the greater, in turn, becomes the default probability. The effect of maturity on default, however, might be ambiguous. On the one hand, the longer the maturity, the smaller is the periodic payment and thus the smaller the probability that a realization of the liquidity process falls below the payment. On the other hand, under a longer maturity there are additional periods at which the liquidity process might fall below the payment, hence a higher probability that default occurs. Which of the effects dominates is contingent upon the parameters of the stochastic liquidity process. Our assumption that the drift of the liquidity process increases over time reinforces the former effect. We therefore assume that the partial derivative of p with respect to t is negative, or $p_t(\cdot)<0$, and the partial derivative of p with respect to r is positive, or $p_r(\cdot)>0$. For simplicity, we might henceforth omit the arguments of $p(\cdot)$.

We assume that the liquidity process induces a periodic default probability, p. No default at any given period thus occurs with probability $1-p$, ant the overall no-default probability is therefore $1-(1-p)^t$. The expected cost to the borrower, of a dollar loan, $C(\cdot)$, is then

[2] In general, we can also include a term structure, which further dictates the size of the periodic payment. While this somewhat adds complexity, no further insight is gained.

$$
\begin{aligned}
C[t,r,p(t,r)] &= (1-p)(\tfrac{1}{t}+r) + pB \\
&+ (1-p)^2(\tfrac{1}{t}+r) + (1-p)p[B-(\tfrac{1}{t}+r)] \\
&+ (1-p)^3(\tfrac{1}{t}+r) + (1-p)^2 p[B-2(\tfrac{1}{t}+r)] \\
&+ \cdots \\
&+ (1-p)^t(\tfrac{1}{t}+r) + (1-p)^{t-1} p[B-(t-1)(\tfrac{1}{t}+r)],
\end{aligned}
$$

where $1/t+r$ is the present value of each of the periodic repayments and B minus the value of the payments already made is the cost of the loan when default occurs, all in present value terms.[3]

The last Equation states that after borrowing one dollar at time zero, at each period, the borrower pays the payment $1/t+r$ with probability p for a duration of t periods, or defaults with probability $1–p$, in which case paying a fixed cost B minus the amount already repaid.

In order to eliminate moral hazard concerning default on the part of the borrower, we set B such that $B>t(1/t+r)$.

Rewriting the last Equation yields

(2)

$$
C[t,r,p(t,r)] = \sum_{j=1}^{t} \left\{ (1-p)^j(\tfrac{1}{t}+r) + p(1-p)^{j-1}[B-(\tfrac{1}{t}+r)(j-1)] \right\},
$$

which can be simplified to

(3)

$$
C[t,r,p(t,r)] = t(\tfrac{1}{t}+r)(1-p)^t + B[1-(1-p)^t].
$$

The first term on the right-hand side of Equation (3) is the expected total repayment under no default, that is, the sum of all payments times the probability of no default. The second term is the expected incurred cost under default. That is, the cost of default, *B*, times the probability of default. Equation (3) is parsimonious because the expected payments until default are offset by the reduction in the cost of default due to those payments. Thus, the expected cost, $C(\cdot)$, is equivalent to the expected cost of a one period and one payment loan, size of which equals to $t(1/t+r)$, with a no-default probability $(1 ? p)^t$, as well as a default cost *B* with a default probability of $1 ? (1 ? p)^t$.

We assume that the cost function, $C[t,r,p(t,r)]$, is decreasing in *t* and increasing in *r*. That is, while raising the mortgage maturity increases both the sum of the payments, $t(1/t+r)$, as well as the probability of their occurrence, it decreases the probability that default occurs and a cost *B* is incurred. We thus assume that the latter effect is stronger than the former. Further, raising the risk premium increases both each of the periodical payments when no default occurs as well as the probability of experiencing a default, and thereby, once again incurring a cost of size *B*. Thus, we posit that

(4)

$$\frac{d}{dt}C[t,r,p(t,r)] \; ? \; 0,$$

and

(5)

$$\frac{d}{dr}C[t,r,p(t,r)] \; ? \; 0.$$

Moreover, we assume that the first term on the right-hand side of Equation (3) – the probability of exhibiting no default times the sum of all periodical payments – is increasing both in *t* and *r*. That is,

[3] We can view the last equation as an "expected present value." Though widely used by actuaries to value various life and elementary insurance policies, it is not generally consistent with term structure theory. This simplification, however, does not affect our results.

(6)

$$\frac{d}{dt}[t(\frac{1}{t} ? r)(1 ? p)^{t}] ? r(1 ? p)^{t} ? (1 ? rt)(1 ? p)^{t}[\ln(1 ? p) ? t\frac{p_t}{1 ? p}] ? 0,$$

and

(7)

$$\frac{d}{dr}[t(\frac{1}{t} ? r)(1 ? p)^{t}] ? r(1 ? p)^{t} ? t(1 ? p)^{t?1} p_r ? 0,$$

where p_t and p_r denote the partial derivative of $p(\cdot)$ with respect to t and r, respectively. Intuitively, a rise in the maturity of the loan increases the total repaid amount, given the risk premium, r. Moreover, it decreases the probability of default, thereby raising the probability of paying the loan in full. These together generate Inequality (6). Further, notice that a larger risk premium incorporates two counter effects: it increases the periodical payment but decreases its probability of occurrence. We assume that the former effect dominates the latter, which altogether yields Inequality (7).[4]

We now introduce the expected, per dollar of a loan, income function of the lender, $I(\cdot)$. It is similar in structure to the expected cost function of the borrower. While borrower's payments are lender's income, the borrower's default cost B might include components that are not a lender's income. Hence in determining the lender's income from the loan, we replace the borrower's cost under default B, with the lenders' income under default before deduction of payments made, D. Note that $D<B$, in particular, $D<t(1/t+r)$.[5] Equivalently to Equation (2), we then write

$$I[t,r,p(t,r)] ? \sum_{j?1}^{t} ?(1 ? p)^{j}(\frac{1}{t} ? r) ? p(1 ? p)^{j?1}[D ? (\frac{1}{t} ? r)(j ? 1)]?,$$

[4] In motivating credit rationing, Jaffe and Russell [1976] show that a greater interest rate on the loan (implying a larger repayment) may decrease the expected repayment due to the rise in the probability of default. While incorporating both effects here, we however assume that a greater risk premium altogether increases the expected repayment.

[5] Recall that $D<t(1/t+r)$ is the lower bound of B and, further, that $D>t(1/t+r)$ implies an arbitrage possibility since the lender's return on investment is above the riskless rate in all states of the worlds.

which simplifies to

(8)

$$I[t,r,p(t,r)] \; ? \; t(\frac{1}{t} \; ? \; r)(1 \; ? \; p)^{t} \; ? \; D[1 \; ? \; (1 \; ? \; p)^{t}].$$

Since $D<B$, without loss of generality, we let D=0. Equation (8) thus becomes

(9)

$$I[t,r,p(t,r)] \; ? \; t(\frac{1}{t} \; ? \; r)(1 \; ? \; p)^{t}$$

Now, suppose two types of borrowers, who are merely differentiated by their default risk. Let p^h (p^l) denote the default probability of the high (low) default risk type, where

(10)

$$p^{h}(t,r) \; ? \; p^{l}(t,r) \quad ? \; t,r \, .$$

We argue that given a menu of mortgage contracts offered by the lender, borrowers' private information may be revealed in a competitive equilibrium. Following Rothchild and Stiglitz (1976), and given p^h, p^l, and Equations (3) and (9), a separating equilibrium is attained, where competitive lenders who maximize expected income offer contracts to borrowers minimizing expected costs,[6] if t^h, t^l, r^h, and r^l sustain:

Lender:

(11)

$$I[t^{h},r^{h},p^{h}(t^{h},r^{h})] \; ? \; t^{h}(\frac{1}{t^{h}} \; ? \; r^{h})(1 \; ? \; p^{h})^{t^{h}}$$

$$? \; t^{l}(\frac{1}{t^{l}} \; ? \; r^{l})(1 \; ? \; p^{l})^{t^{l}} \; ? \; I[t^{l},r^{l},p^{l}(t^{l},r^{l})],$$

High-risk borrower:

[6] Since we fix the size of the loan, then maximizing income (minimizing cost) and maximizing profit is redundant on the part of lenders (borrowers).

(12)

$$C[t^h, r^h, p^h(t^h, r^h)] \,?\, t^h(\frac{1}{t^h} \,?\, r^h)(1 \,?\, p^h)^{t^h} \,?\, B[1 \,?\, (1 \,?\, p^h)^{t^h}]$$

$$\,?\, t^l(\frac{1}{t^l} \,?\, r^l)(1 \,?\, p^h)^{t^l} \,?\, B[1 \,?\, (1 \,?\, p^h)^{t^l}] \,?\, C[t^l, r^l, p^h(t^l, r^l)],$$

Low-risk borrower:

(13)

$$C[t^l, r^l, p^l(t^l, r^l)] \,?\, t^l(\frac{1}{t^l} \,?\, r^l)(1 \,?\, p^l)^{t^l} \,?\, B[1 \,?\, (1 \,?\, p^l)^{t^l}]$$

$$\,?\, t^h(\frac{1}{t^h} \,?\, r^h)(1 \,?\, p^l)^{t^h} \,?\, B[1 \,?\, (1 \,?\, p^l)^{t^h}] \,?\, C[t^h, r^h, p^l(t^h, r^h)],$$

where t^h (r^h) and t^l (r^l) is the maturity (risk premium) of the mortgage loan selected by the high and low risk type borrower, respectively.

We then claim that

Proposition 1: There exists a unique separating equilibrium under which the low (high) default risk type borrower selects shorter (longer) maturity and lower (higher) risk premium mortgage loan contract. That is, $t^l<t^h$ and $r^l<r^h$.

Proof: Equation (11) together with Inequalities (6), (7), and (10) imply that it cannot be the case that both $t^l?t^h$ and $r^l?r^h$ are true. Likewise, Inequality (12) combined with Inequalities (4) and (5) imply that it cannot be the case that both $t^l?t^h$ and $r^l<r^h$ are true. The last two restrictions, then, imply that $t^l<t^h$. In addition, Inequality (13), together with Inequalities (4) and (5) imply that it cannot be the case that both $t^l?t^h$ and $r^l?r^h$ are true. But this latter result together with the previous finding that $t^l<t^h$ implies that $r^l<r^h$. Finally, the uniqueness property of the attained equilibrium follows the ordinary result of models a la Rothchild and Stiglitz (1976). ?

Intuitively, due to his exogenous lower probability of default, it is less costly for the low-risk type borrower to select a contract that endogenously increases the default probability, i.e. a shorter maturity contract. The motivation for choosing that contract is to identify one-self as a safer borrower type and thereby be offered a lower risk premium.

Consider now that in addition to the discussed pair of borrower types, there exists an additional such pair. As before, in the spirit of Equation (10) we assume that there are no overlapping default probabilities among all four borrowers. We will call a set of mortgage loan contracts offered by lenders to borrowers in a Rothchild-Stiglitz equilibrium of the type discussed earlier, a "menu." Suppose that the competitive lenders offer two menus of two contracts each with maturity and risk premia designed for the two non-overlapping pairs of borrowers. As before we assume that the "population" parameters are common knowledge but the individual types are private information. The lenders offer the contracts designed for the low (high) risk menu to the pair of borrowers with a "good" ("bad") "credit record," $R,\ R ? \{0,1\}$. A "good" ("bad") credit record, R=1 (R=0), reflects a "good" ("bad") credit history of a borrower. Maintaining a good credit record is costly to the borrowers, as they must not ever default on a loan. If it is always (not) worthwhile for the low (high) risk pair borrowers to maintain a good credit record, there will be a separating signaling equilibrium between the pairs. Lenders, not offering the appropriate contacts to the borrowers will lose customers and will receive lower income from the others, and borrowers not truly signaling their type will pay higher costs. Let borrowers value function be the sum of their, previously developed, expected per dollar loan cost, C, plus the credit record signal cost of their risk type. Then borrowers' cost minimization problem is

(14)

$$\underset{R}{Min}\{V(p) ? C(p) ? pF(R)\},$$

where *p* is their default type, we suppressed the other arguments of *C*, and *F* is a strictly monotone function of *R*. Then, it is necessary for a separating-by-pairs signaling equilibrium that the optimal values of *V*, for the low (high) risk pair are lower when *R*=1 (*R*=0).

Given the signaling and screening mechanisms discussed above, we can state the following proposition.

Proposition 2: There exists a fully separating signaling-screening equilibrium in which, borrowers' first signal their unobservable default risk types by observable credit records and are clustered into subsets, and, then, self-select themselves by choosing from subsets dependent menus of mortgage contracts of different maturity.

While we observe a combined signaling-screening equilibrium in the real world, it is interesting to note the following.

Proposition 3: The separating signaling-screening equilibrium is never Pareto inferior to a corresponding separating screening equilibrium.

Consider a separating signaling-screening equilibrium as described above and a screening only equilibrium that separates among the same four types. In a Rothchild-Stiglitz screening equilibrium, only the "worst type" receives a "first best" contract. In contrast, in a signaling-screening equilibrium there must be at least two "first best" contracts. In addition, the signaling costs of maintaining good credit records are sums transferred from borrowers to lenders thus not socially wasted.

3 Conclusions

In this paper we combine signaling and screening mechanisms to explain both the use of credit records and the offering of menus of contracts in the mortgage market. While we make assumptions about sensitivities of functions to different parameters in an attempt to be consistent with stylized facts, the existence of a combined signaling-screening equilibrium does not depend on these assumptions.

In our model, borrowers first signal their default risk type by “choosing” a credit history. Credit records, however, only partially separate borrowers’ risk types, clustering them into subsets. Then, focusing on each subset of borrowers, lenders screen each subset by offering a different menu of mortgage loan contracts with varying pairs of risk premium and maturity.

As it turns out in equilibrium, due to the lower probability of default, it is less costly for safer borrowers to acquire better credit records and then to select shorter maturity mortgages, thereby benefit from lower risk premium.

We show that the identified signaling-screening separating equilibrium is Pareto superior to the ordinary screening equilibrium a la Rothchild and Stiglitz (1976). Under the latter, it is only the riskiest borrow in the population that manages to obtain his first best choice in equilibrium. In fact, the safer the borrower the farther becomes his equilibrium selection from his first best. However, in the signaling-screening equilibrium, due to the clustering of subsets, the mechanism allows the riskiest borrower in each subset to select his first best. Moreover, most borrower types will be closer to their first best contract.

While, for simplicity, we model two pairs of borrower types, our framework may apply to numerous subsets of numerous types each.

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