Mortgage Securitization and Risk*

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Abstract

Securitization is typically seen as a risk-sharing technique; less attention is paid to how risk types affect the equilibrium and optimal secondary market sizes. We use a standard equilibrium model with spatial differentiation to characterize the effects of different risk types on secondary markets and ultimate mortgage borrowers. We find that: (1) Market risks (e.g. liquidity and origination risk) increase secondary market trading volume but do not necessarily lead to securitization *per se*; (2) Idiosyncratic risks (e.g. credit risk) do lead to securitization as well as increasing secondary market volume; and (3) Aggregate risks (e.g. prepayment risks) tend to decrease secondary market volume.

Also, some secondary markets are fragmented while others are highly standardized. We provide conditions for the equilibrium emergence of a single secondary market, and for the optimality of such a market.

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1 Introduction

Mortgage originators face four fundamental sources of risk. First, the risk that they are unable to originate the desired volume of mortgages (*origination risk*); second, that the market price of mortgages may fluctuate, hampering their efforts to maintain a diversified portfolio (*liquidity risk*); third, that individual mortgages may default (*credit risk*); and fourth, that mortgages may prepay, losing a fraction of their value (*prepayment risk*).

We begin our analysis with the first two forms of risk. We use the sense of liquidity and origination risk developed in the model of Economides and Siow (1988). We add an idiosyncratic shock (which we associate with credit risk) and an aggregate shock (which we associate with prepayment risk) to the model.

In the Economides and Siow model, agents are spatially separated and must pay a travel cost to attend a nearby market, where they can trade their endowments. In our model, originators concentrate on separate borrower populations and must pay a cost to understand the true value of mortgages originated from among other borrower populations. These borrower populations can be thought of as being geographically or socio-economically distinct (or both).

Originators want to hold a diversified portfolio of mortgages (or mortgage-backed securities) and cash. They face an initial origination risk, which is the risk of originating more or fewer mortgages than they desire to hold. Originators can pay the travel costs associated with going to the nearest market in order to trade with other originators and rebalance their portfolios. These markets may be relatively small, and thus feature little diversification of origination risk. Participants will face large fluctuations in the market-clearing price of mortgages. We identify these fluctuations with liquidity risk.

In this basic setup, originators do not have a preference for MBS over whole mortgage loans. They merely want to buy or sell some mortgages to maintain portfolio balance. They are indifferent to *which* mortgages wind up in their portfolio. By adding an idiosyncratic shock, however, market participants will want maximum diversification. They will pool their mortgages and then trade shares in the resulting market-wide security. Thus idiosyncratic risk (which we identify with credit risk) will lead to proper securitization and to larger and more liquid markets.

We then introduce an aggregate shock to the value of mortgages. We identify this shock with prepayment risk because mortgage refinancing is highly correlated across borrowers. Secondary markets, in our model, cannot help to diversify aggregate risks. We show that such aggregate risks tend to shrink equilibrium secondary market volume.

Our model also allows us to consider the fragmentation of secondary markets. We introduce a special location equidistant from all originators. This can be thought of as a set of mortgage standards that are equally costly for all originators to meet. We characterize the conditions under which originators prefer this central market to a system of smaller, regional markets. We identify an arrangement with several local markets as a fragmented secondary market system, and the arrangement in which all mortgages are traded in a central location as a highly standardized secondary market.

Finally, we show that larger and more liquid secondary markets lead to lower mortgage interest rates for the final mortgage borrowers.

In section 2 we develop the basic model; we introduce idiosyncratic risk in section 3 and prepayment risk in section 4. Although our model captures many of the salient features of mortgage markets, in our conclusion we discuss some institutional features missing from our model and how, in future work, we might capture them.

2 Basic Model and Results

In this section we lay out the simplest version of our model, in which mortgages are not subject to prepayment or credit risk. In this basic version of the model, secondary markets emerge only to hedge origination risk. Institutions will trade on these markets solely in order to smooth their portfolios. We show that in a symmetric non-cooperative equilibrium, secondary mortgage markets might be too small. As a result, mortgage interest rates paid by the ultimate borrowers will be too high relative to the social optimum.

2.1 Originators

The basic setup of our model follows that of Economides and Siow (1988). Mortgage originators (that is, lenders) are arranged at unit distances along a circle; there are Γ originators, so the circle will be of circumference $\Gamma - 1$ and radius $(\Gamma - 1)/(2\pi)$. Location on the circle can be thought of in purely spatial terms, or in terms of the characteristics of the underlying borrowers. Originators will have to pay a cost t to "travel" one unit of distance. This can be thought of as an information revelation cost. The farther a secondary market is located from an originator, the greater the cost to participate in that market.

Each originator acts as a monopolist with respect to the potential mortgage borrowers located at its position on the circle. Mortgage borrowers are assumed to have utility functions that result in demand functions with elasticity $-\eta$ with respect to the gross mortgage interest rate, r, charged by the originator/lender.

For simplicity, we assume that originators begin with a unit of cash on hand that they may convert to a mortgage with probability $\pi(r)$, where $\pi'(r)r/\pi(r) = -\eta$. The endowment of each lender i is therefore either a unit of cash (if it fails to originate a mortgage) or a unit of mortgage times the gross interest rate charged, r_i (if it originates a mortgages).

Originators have utility over the final mix of mortgages and cash in their portfolio. Ideally, for a given dollar portfolio, originators want to hold a constant fraction, α, of that portfolio in mortgages. Their utility falls smoothly as they deviate from this plan; at the extremes, where they hold all mortgages or all cash, their utility is zero. Such preferences can easily be implemented with Cobb-Douglas utility over cash and mortgage holdings. Thus, we write the utility of an originator as:

$$U(m_i, c_i) = (m_i)^{\alpha} c_i^{1-\alpha} - td_i,\ 0 < \alpha < 1,\ t > 0. \tag{1}$$

Here, d_i denotes the distance traveled by the originator.

2.2 Markets

Markets are spatially localized groupings of mortgage originators that trade mortgages and cash with each other. We identify these markets as specialized secondary markets. Larger markets will offer better credit diversification and more liquidity, but will also require larger travel distances. A section of this spatial arrangement is shown in figure 1.

If a market has N participants, some originators had to travel a distance of $(N-1)/2$ units to come to market. Originators make their decision of how far to travel before they know whether they successfully originated a mortgage or not.

Some market participants will bring cash and others mortgages to the market. If a lender originates a mortgage, its endowment is $\overline{m}_i = 1$ and $\overline{c}_i = 0$; if the lender does not originate a mortgage, its endowment is the opposite: $\overline{m}_i = 0$ and $\overline{c}_i = 1$. Denote the average levels of these variables in a particular market as $\overline{C}$ and $\overline{M}$. Note that $\overline{C}$ and $\overline{M}$ are random variables: in a market with N participants, $\overline{C}$ can take on the $N+1$ values $\{0, 1/N, \ldots, 1\}$.

Participants in a given market will seek to maximize utility subject to the budget constraint that $c_i + Pm_i \leq \overline{c}_i + Pr_i\overline{m}_i$, where P is the relative price of mortgages in the market and r_i is the gross mortgage rate charged by lender i. Notice that consumption (portfolio holding) is written in *end of period* terms, while endowments are written in *beginning of period* terms. By assumption, cash realizes a gross return of one over the period; mortgages realize a gross return of r_i over the period. Thus we multiply the *quantity* of mortgages originated, $\overline{m}_i$, by the price of mortgages, P, and the mortgage coupon, r_i.

Also, note that the market-clearing price, P, will vary across markets depending on the relative scarcity of mortgages in each market. Even markets with the same number of participants will have different *ex post* realizations of mortgage and cash endowments.

In a symmetric equilibrium, where all lenders charge the same mortgage rate,

$r_i = \overline{r}$, the relative price of mortgages is given by:

(2) $$P = \frac{\alpha}{1-\alpha} \frac{\overline{C}}{\overline{r}(1-\overline{C})}.$$

The value of a lender's endowment can be written as:

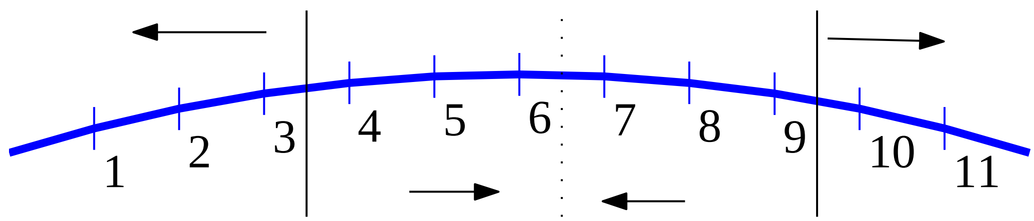
$$z_i = \overline{c}_i + \frac{\alpha}{1-\alpha} \frac{\overline{C}}{\overline{\overline{M}}} \frac{r_i}{\overline{r}} \overline{m}_i.$$

The final portfolio holdings of originators (after trading is complete), c_i and m_i, are $c_i = (1-\alpha)z_i$ and $m_i = \alpha z_i / P$. The indirect utility of an originator given P is: $aP^{-\alpha} z_i - td$, where $a = \alpha^\alpha (1-\alpha)^{(1-\alpha)}$. An originator's utility will depend on whether or not it successfully originated a mortgage and on the prevailing equilibrium price in the local market:

(3) $$V_{1i}(P) = \begin{cases} aP^{-\alpha} - td & \text{with probability } 1 - \pi(r_i), \\ ar_i P^{1-\alpha} - td & \text{with probability } \pi(r_i). \end{cases}$$

When the market is completely made up of lenders of the same type (that is, who have all originated a mortgage, or who have all failed to do so), the equilibrium price will not be defined. However, all lenders will derive zero utility from their portfolio holdings, so that a given lender's utility will just reflect its travel costs: $-td$.

FIGURE 1: Originators and Markets



NOTE. Figure shows a sample arrangement of originators (the numbered ticks along the line) and markets; originators between the solid vertical lines travel to the market indicated by the dotted vertical line. Originators travel in the direction indicated by the arrows.
In this example, each market has six participants ($N = 6$); the market located at position 6.5 will attract originators 4, 5, 6, 7, 8 and 9. Originators 4 and 9 must travel the farthest, a distance of $(N - 1)/2$ or 2.5 units.

2.3 Equilibrium

Our goal is to characterize the equilibrium number of participants (and hence liquidity) in secondary markets. First, however, we have to derive the equilibrium mortgage interest rate charged by lenders. We will confine our analysis to symmetric Nash equilibria in which all originators take as given a common market size, N, and interest rate, $\overline{r}$.

We know from equation (2) that in a market of size N, the relative price of mortgages, P, is distributed binomially (with success probability $\pi(\overline{r})$) among the $N + 1$ values $P_j = \{0, 1/(N - 1), 2/(N - 2), 3/(N - 3), \ldots, N/0\}$. From equation (3) we know that the utility of all participants will be zero in the extreme cases when all market participants have the same endowment.

Lenders choose mortgage interest rates, r_i, to maximize their expected utility taking as given N and $\overline{r}$:

$$
\begin{aligned}
(4) \qquad & \max_{r_i} \mathbb{E}_N\big\{V_{1i}(P)\big\}, \\
\Leftrightarrow & \max_{r_i} \sum_{j=0}^{N} b_j V_{1i}(P_j), \\
\Leftrightarrow & \max_{r_i} \sum_{j=1}^{N-1} b_j \left\{ \pi(r_i) \left[a r_i P_j^{1-\alpha} \right] + \big(1-\pi(r_i)\big) \left[a P_j^{-\alpha} \right] \right\} - td, \\
\text{where } & P_j = \alpha\big[\overline{r}(1-\alpha)\big]^{-1}\big[1-(j/N)\big]\big[j/N\big]^{-1}, \; j = 1, \ldots, N-1 \\
& b_j = \overline{\pi}^j (1-\overline{\pi})^{N-j} \binom{N}{j}.
\end{aligned}
$$

Here $\overline{\pi}$ denotes the expected average success probability of all other participants, which the originator takes as given. (In a symmetric equilibrium $\overline{\pi} = \pi(\overline{r})$.)

Even before we characterize the equilibrium, we can derive a relationship between market liquidity (the number of participants) and the mortgage interest rate charged to borrowers.

PROPOSITION 1 *Markets with greater liquidity will feature lower mortgage interest rates charged to final borrowers. That is, $\overline{r}$ is decreasing in the number of market participants, N.*

PROOF. The lender's maximization problem can be written:

$$
\max_{r} \; r\pi(r)\, \mathbb{E}_N \left\{ P^{1-\alpha} \right\} \; + \; [1-\pi(r)]\, \mathbb{E}_N \left\{ P^{-\alpha} \right\},
$$

where $\mathbb{E}_N\{x\}$ denotes the expected value of a random variable x over the $N+1$ outcomes of the distribution formed by N i.i.d. trials of a Bernoulli random variable. The lender will choose a value of r that satisfies:

$$
r = \frac{\eta}{\eta - 1} \frac{\mathbb{E}_N \left\{ P^{\alpha-1} \right\}}{\mathbb{E}_N \left\{ P^{-\alpha} \right\}}. \tag{5}
$$

Recall that $\eta > 1$ is the constant price elasticity of demand for mortgages by the ultimate retail borrower. By inspection, as N rises the numerator of equation (5) falls and the denominator rises. Thus the optimal choice of r is lower for all lenders participating in larger markets. □

By solving equation (4) we can construct the agent's concentrated value function, which is the expected utility written just as a function of market size, N:

$$V_1(N) = W_1(N) - td, \text{ where: } W_1'(N) > 0, W_1''(N) < 0. \tag{6}$$

The closed form solution for $W_1(N)$ is complicated, especially for small values of N (at the limit of large N, prices follow a Gaussian distribution). However, Economides and Siow (1988) show that $W_1(N)$ is increasing and concave for large N.[1]

A symmetric Nash equilibrium is defined as a market size, N, and associated mortgage interest rate, r that satisfy the following conditions:

1. The marginal participant in a market (the participant with the maximum travel distance) does not prefer the neighboring market, that is, a market with one more participant:

$$\begin{aligned} & V_1(N) \geq V_1(N+1) \\ \Leftrightarrow \; & W_1(N) - t(N-1)/2 \geq W_1(N+1) - tN/2 \\ \Leftrightarrow \; & W_1(N+1) - W_1(N) \leq t/2. \end{aligned}$$

[1] Note that for small N $W_1(N)$ is not generally concave, nor indeed monotone. However, for a broad range of parameter values, the $W_1(N)$ function becomes well behaved for $N \geq 10$. The number of participants in secondary mortgage markets comfortably exceeds this.

We will write this condition as $W_1'(N) \leq t/2$.

2. Participating in the market of N persons is better than autarky for all participants, $V_1(N) \geq 0$. For the marginal participant, this is equivalent to:

$$\frac{W_1(N)}{N-1} \geq t/2.$$

For low enough travel costs, t, there will be a range of equilibrium market sizes. The first condition, which can be written as $W_1' \leq t/2$, defines a minimum equilibrium market size, $\underline{N}_1$. The second condition defines an upper bound on N, $\overline{N}_1$. (To see this, note that the condition must be violated for any t if N is large enough.) Thus the equilibrium market size, $N^e{}_1$, will lie in the range $N^e{}_1 \in [\underline{N}_1, \overline{N}_1]$.

2.4 Optimality

The optimal market structure is potentially quite different from the equilibrium described above. The social planner seeks to optimize the expected utility of all secondary market participants (or potential participants). The utility of the representative lender is given by:

$$S_1(N) = W_1(N) - t\overline{d}_N.$$

Here $\overline{d}_N$ is the average distance traveled by all market participants:

$$\overline{d}_N = \frac{2}{N}\left(\frac{1}{2} + \frac{3}{2} + \cdots + \frac{N-3}{2} + \frac{N-1}{2}\right) = N/4.$$

The social planner's first-order condition for optimality is thus $W'(N^\star) = t/4$; at the same time, the smallest possible equilibrium market size satisfies $W'(\underline{N}_1) = t/2$. As a result, we know that $\underline{N}_1 < N^\star$; the smallest equilibrium market size is socially suboptimal. From proposition 1, we also know that the mortgage interest rate paid by borrowers in this equilibrium will be too high.

2.5 The Central Location

So far we have not considered the circle's center as a potential location for a market. This position is special because it is equidistant from all originators. It can be thought of as a set of uniform underwriting standards which cost all originators the same amount to meet.

A centrally-located can be seen as just a very large version of the markets we have already discussed. However, for technical reasons we will additionally assume that all idiosyncratic risks (origination and credit risk) will disappear at the center. This assumption is equivalent to assuming that the aggregate values of all idiosyncratic risks are known by all participants ahead of time, but that the participants do not know how these risks will be divided among them.

This assumption allows us to write the utility of each originator who participates in the central market as:

$$\overline{V}_1 = V\left(E\{P\}\right) = \overline{W}_1 - t(\Gamma - 1)/(2\pi).$$

Note that the expected utility (not counting travel costs) of participating in the central market, $\overline{W}_1$, will exceed the expected utility (again, without travel costs) of participating in any regional market of fewer than $\Gamma - 1$ participants

$$W_1(N) \leq \overline{W}_1, N \leq \Gamma - 1.$$

Here $\Gamma - 1$ is the circumference of the circle and $d_c = (\Gamma - 1)/(2\pi)$ is the radius, or distance to the center of the circle. (and hence the travel cost associated with the centralized market is td_c).

Define $\Delta_1(N)$ to be the expected utility loss (excluding travel costs) from participating in a regional market of N participants as opposed to the central market: $\Delta_1(N) \equiv \overline{W}_1 - W_1(N)$. The social planner would prefer the central market to the arrangement of regional markets iff:

$$\Delta_1(N^\star) \geq t\left(\frac{\Gamma - 1}{2\pi} - \frac{N^\star}{4}\right).$$

A central market will be a symmetric non-cooperative equilibrium if each potential participant values travel to the center over autarky:

$$\overline{W}_1 - t\frac{\Gamma - 1}{2\pi} \geq 0.$$

Without more structure, we cannot establish a necessary relationship between the central market being an equilibrium and its being optimal.

However, an intuitive equilibrium refinement is to require that equilibria featuring regional markets satisfy the condition that each participant in the regional market prefer it to the central market. This will have the effect of bounding the *maximum* regional market size because the agent most likely to defect from a regional market is the farthest one from the center:

$$N \leq 1 + \frac{\Gamma - 1}{\pi} - \frac{2\Delta_1(N)}{t}$$

Thus, competition from a centralized market will draw off disaffected members of large regional markets. In turn, this effect will eliminate these sizes of regional markets as potential equilibria.

2.6 Discussion

We can draw several insights from this model already. First, we have a precise definition of liquidity and an explicit mechanism by which secondary market liquidity benefits final consumers.

Second, note that there is a range of equilibrium liquidity levels. This fits with the intuition that financial market liquidity is unstable. In a repeated version of this basic setup, both the price of mortgages in a given market and the equilibrium liquidity level in that market could change radically over time.

Third, the existence of a single centralized secondary market can eliminate equilibria with *larger* regional markets. However, equilibria with too few market participants (relative to the optimum) are more likely to withstand competition from the centralized secondary market. This is because such markets feature relatively low travel costs for all participants.

3 The Effect of Credit Risk

In this section we introduce an idiosyncratic shock to mortgages (credit risk), so that lenders have an incentive to sell their own mortgages in exchange for shares in the market-wide average mortgage. Without credit risk, lenders have no incentive to exchange their own mortgages for those originated by others in the same market.

3.1 Equilibrium and Optimal Markets Under Credit Risk

We model credit risk as an i.i.d. probability λ that a given lender's mortgage, originated an interest rate of r, decays to a portfolio value of $(1-\theta)r$.[2] A portfolio comprising N mortgages will have a total end-of-period value distributed as:

$$\Pr\{\text{Portfolio Value} = N - X\theta\} = b_X \lambda^X (1-\lambda)^{N-X},$$
$$\text{where: } X = 0, 1, \ldots, N-1, N, \text{ and } b_X = \lambda^X (1-\lambda)^{N-X} \binom{N}{X}.$$

[2] It is reasonable to suspect that in reality mortgages located close to each other (in product space or geographic space) would share credit risk characteristics and hence have a correlated probability of default. However, in our model the main effect of credit risk is to increase the optimal and equilibrium market sizes. Spatial correlation of credit risk only increases this effect.

Thus if the agent purchases a quantity m_i of mortgages to portfolio, the actual portfolio value of the mortgages will be given by $(1-\theta x)m_i$, where x takes on the $N+1$ values $\{0, 1/N, \ldots, 1\}$ with the probabilities b_X described above.

Thus we can construct the value function of an originator, V_{2i}, in the same way that we did in equation (3):

$$(7) \quad V_{2i}(P) = \begin{cases} aP^{-\alpha} \sum_x b_x (1 - x\theta)^\alpha - td & \text{with probability } 1 - \pi(r_i), \\ ar_i P^{1-\alpha} \sum_x b_x (1 - x\theta)^\alpha - td & \text{'with probability } \pi(r_i). \end{cases}$$

The term $\sum_x b_x(1-x\theta)^\alpha$ represents the utility cost of the extra uncertainty accompanying idiosyncratic risk. In the same way that we defined the concentrated value function $W_1(N)$ in equation (6) using V_{1i}, we can define $W_2(N)$ using V_{2i}.

Notice immediately that, because of the added uncertainty associated with credit risk, W_2 will in general be below W_1 and have a steeper slope:

$$W_2(N) \leq W_1(N),\ W_2'(N) \geq W_3'(N),\ N < \Gamma - 1.$$

However, because of our assumption that there is no aggregate credit risk, the value of being in the central location is the same: $\overline{W}_2 = \overline{W}_1$.

This characterization of $W_2(N)$ leads to the following propositions comparing equilibria with and without credit risk:

PROPOSITION 2 *The smallest equilibrium market size will be larger with credit risk than without, $\underline{N}_2 > \underline{N}_1$, but it will still be smaller than optimal, $\underline{N}_2 < N_2^\star$.*

PROOF. Recall that the smallest equilibrium market sizes are determined by the relations $W_{1,2}'(\underline{N}_{1,2}) = t/2$. With credit risk, $W_2'(N) \geq W_1'(N)$, so $\underline{N}_2 \geq \underline{N}_1$.

However, the social planner's problem requires $W'_{1,2}(N^\star_{1,2}) = t/4$; thus, $\underline{N}_2 < N^\star_2$. □

PROPOSITION 3 *The largest possible equilibrium secondary markets are the size with or without credit risk.*

PROOF. The largest regional equilibrium markets that withstand competition from the central location are defined by the relation $W_{1,2}(N) - t(N-1)/2 \geq \overline{W}_{1,2} - t(\Gamma - 1)/(2\pi)$. The LHS is lower with credit risk than without while the RHS is the same with or without credit risk. □

3.2 Discussion

The addition of credit risk makes smaller regional markets less useful as a means of sharing risk. However, interestingly, the smallest equilibrium market size and the optimal market size both rise in lockstep. Thus credit risk does not eliminate the problem of fragmented regional markets that are too small.

At the same time, credit risk threatens the viability of larger regional markets. Intuitively, the expected utility derived from being a participant in the central location is the same whether or not credit risk is present. However, the expected utility of being a participant in any regional secondary market is lower. Thus, the marginal participant in a regional market is likelier to forsake the regional market in favor of the market located at the center.

4 The Effect of Prepayment Risk

In this section we introduce an aggregate shock that affects all mortgages equally (prepayment risk). As with credit risk, we model this shock as destroying a proportion ϕ of the portfolio value of a mortgage. Unlike credit risk, the shock is common to all mortgages; with probability μ all mortgages suffer the aggregate shock.

By analogy from the previous section, prepayment risk results in a value function $W_3(N)$ that has the following relationship to $W_1(N)$:

$$W_3(N) \leq W_1(N), W_3'(N) = W_1'(N).$$

That is, the level of W_3 is lower (because of the increased risk), but the slope is unchanged, because increasing the number of participants does nothing to relieve this risk. Also, because the central location has no special ability to relieve this risk, $\overline{W}_3 < \overline{W}_1$.

The optimal market size is unchanged, $N_3^\star = N_1^\star$, as is the lowest possible equilibrium market size, $\underline{N}_3 = \underline{N}_1$. However, the largest possible regional market decreases.

PROPOSITION 4 *The largest possible regional secondary market is smaller when prepayment risk is present than when it is absent.*

PROOF. Intuitively, prepayment risk lowers the utility of participating in any market. Thus, autarky or the central market are both relatively more attractive. Formally, the upper bound on regional secondary markets is determined by the relation $V_{1,3}(\overline{N}_{1,3}) \geq 0$. Prepayment risk pushes down the level of $V_3(N)$ relative to $V_1(N)$. □

5 Conclusion

In this paper we studied the effect of different mortgage risks on secondary markets. Secondary markets, in our model, exist primarily to share idiosyncratic risks, specifically origination and credit risk.

We showed that a non-cooperative symmetric equilibrium may replicate the social optimum, but that the smallest equilibrium market is generally smaller than is socially optimal.

Further, we showed that the presence of a unique marketplace that is equidistant from all originators can, under certain circumstances, be a symmetric noncooperative equilibrium. However, even if one equilibrium features all agents going to this location, other equilibria that feature fragmented regional markets continue to exist. This result holds in the presence of idiosyncratic shocks (credit risk) and aggregate shocks (prepayment risk).

Thus, a properly-designed subsidy scheme to entice originators to away from the regional markets to the central market might improve social welfare. An improperly-designed scheme, however, might not increase social welfare and might even lead to decreased risk sharing. We plan to characterize the nature of the optimal subsidy in a future version of this study.

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