Foreclosure Auctions

Andras Niedermayer
University of Mannheim

Artyom Shneyerov
Concordia University, CIREQ, CIRANO

Pai Xu
University of Hong Kong, Hong Kong

This Draft: October 28, 2014

Abstract

We develop a novel theory of real estate foreclosure auctions, which have the special feature that the lender acts as a seller for low and as a buyer for high prices. We get three predictions: (i) lenders' bids are bunched at the amount owed, (ii) if all auctions observed exhibit a common value component, there are gaps in lenders' bids, (iii) if there are both independent private values and common value component auctions, there will be no gaps, but non-monotonicity of the probability of sale in the reserve price. Using novel data from Palm Beach County (US), we show that (i) and (iii), but not (ii) are consistent with the data. Further, the data is consistent with the claim that adverse selection plays less of a role for securitized than for non-securitized mortgages. Our theory also allows an analysis of the welfare effect of judicial versus non-judicial foreclosures.

Keywords: foreclosure auctions, common value component, securitization

JEL Codes: to be added

1 Introduction

Foreclosure auctions of real estate have a substantial economic impact. In 2013, 16.2% of residential sales in the U.S. were foreclosure related (foreclosure auctions or sales of real estate owned by a lender).[1] Foreclosures were one of the major concerns during the economic crisis, with many home owners losing their property because of the drop of real estate prices.

[1] See `http://www.realtytrac.com/Content/foreclosure-market-report/december-and-year-end-2013-us-residential-and-foreclosure-sales-report-7967`.

We develop a novel theory of foreclosure auctions, thereby incorporating the institutional specificities of foreclosures. A foreclosure auction is run by a government agency (in our data set the Clerk and Comptroller's Office) after a mortgagee stopped making payments to the lender. The lender (typically a bank) and third party bidders (typically realtors) participate in this auction. Payments up to the amount owed (the judgment value) are paid to the lender, payments above the judgment value (if any) are paid to the owner of the property. The owner typically does not participate. In such an auction, the bank essentially acts as a seller below the judgment value (its bid being a reserve price) and as a buyer above the judgment value (its bid being a regular bid by a buyer in an auction).

In foreclosure auctions, the bank is likely the better informed party. When the property is in foreclosure, the owners have little incentive to take proper care of it. Moreover, in many cases owners abandon houses altogether, taking with them whatever they can get their hand on. The vacant rate is very high for foreclosed houses. For example, the city of Cleveland estimated in early 2009 that at least 10,000 (or one in 13) of *all* its houses were vacant while the county treasurer estimated that the number was 15,000 – 50% higher.[2] Most mortgages include provisions that protect lender's interest in the property if the owner vacates the property. Such provisions may include allowing the lender's representative to enter the property to make repairs and providing regular maintenance such as turning utilities on and off.[3] This means that the lender, especially if it has a local presence in the market (more on this below), will have access to the foreclosed property and will be able to assess its condition much better than the realtors, who will in most cases have to content with an outside visual inspection. This is the key information asymmetry in this market.

We derive participants' bidding strategies in a setup with a common value component that nests the independent private values case. The theory has three striking empirically testable implications. First, there is bunching of banks' bids at the judgment amount. Second, if one could perfectly separate a data set into auctions with and without a common value component one should observe the following. In auctions with a common value component there is a gap in banks' bids below and above the judgment amount. In independent private value auctions,

[2]See http://www.courtinnovation.org/sites/default/files/abandoned_property.pdf

[3]See http://www.nolo.com/legal-encyclopedia/deceptive-foreclosure-practices-when-banks-treat-occupied-homes-vacant.html

there are no gaps. Third, if one cannot perfectly separate auctions with and without a common value component one should observe the following *selection effect*. For prices slightly below the judgement amount, the private value auctions are selected into the observable sample. This is because there is a *gap* below the judgement amount under common values. For prices slightly above the judgement amount, both private and common value auctions are selected. As the probability of sale ("demand") is lower under common values due to the effect of adverse selection, the observable demand will exhibit a downward jump at the judgement value. This *demand discontinuity* due to the selection effect is a testable prediction under common values.

We have collected a novel data set with foreclosure auctions from Palm Beach County in Florida. We have data on 43,015 auctions from 2010 to 2013 with the total judgment amount being $13.3bn and the sum of winning bids being $3.3bn. The data reveals that bunching indeed occurs at the judgment value. We also observe that the probability of sale increases just below and just above the judgment amount as theory predicts. However, we do not observe gaps below and above the judgment amount, which suggests that some auction in our data set are with and some without a common value component. This is further supported by the empirical evidence that the demand exhibits a discontinuity at the judgement value, pointing, as we have argued, to the presence of common value auctions in our dataset.

A major concern during the financial crisis was the securitization of mortgages. Originating banks securitized their mortgages through securitization agencies (mostly the Government Sponsored Enterprises Freddie Mac and Fannie Mae), the securitized assets were then sold on the capital market. The claim was often made that banks excessively granted mortgages and securitized low quality mortgages, thus shifting the burden to the holders of securitized assets and Government Sponsored Entities (and ultimately to the tax payer).

For non-securitized mortgages the plaintiff in the foreclosure auction is typically a local bank that is likely to have private information about the quality of the property being sold. For securitized mortgages the plaintiff is typically a non-local bank that acts as a trustee for a pool of securitized mortgages. Such a non-local trustee may not have the resources to inspect each of the foreclosed properties in the pool. One would therefore expect the plaintiff to have less private information for securitized mortgages. In this setting, one would expect the adverse selection effect to be much smaller, with the observable implication of a much less pronounced discontinuity in the demand at the judgement value. Our empirical findings support this prediction.

What are the welfare implications of common values and the associated adverse selection in foreclosure auctions? Building on the insights in Cai et al. [2007], Jullien and Mariotti [2006] and Lamy [2010], we show that seller bids in the foreclosure auction under common values involve a *signalling premium* for bids below the judgement value. That is, they are higher relative to what they would have been if the realtors knew the bank's information. This introduces a further distortion, on top of the usual deadweight loss stemming from the bank's monopoly position as the seller. Fro the bids above the judgement value, on the other hand, there is no distortion, as the bank will act as a buyer, and the English auction will allocate the house efficiently.

Roughly half of the states in the U.S. (including Florida) only allow judicial foreclosure, i.e. the foreclosure auction has to be run by a court with rules as the ones described in this article. The other half of the states allow for both judicial and non-judicial foreclosures. If the mortgage contract contains a power of sale clause, the bank can choose a non-judicial foreclosure in case of a failure to repay, i.e. the bank can directly seize the property and sell it without going through a court.

The power of sale allows the bank to market the property, and to verifiably disclose, through inspections, the information regarding its condition. This eliminates the signalling premium, but introduces another distortion. The bank, acting as a de facto owner of the property, is no longer obligated to pay the owner back any auction proceed above the judgement value. Thus the monopoly price distortion now extends to prices above the judgement value. So the overall welfare effect of the power of sale is ambiguous. The estimation of this effect would require structural estimation of a foreclosure auction, and is left for future work.

2 Model

Consider the owner, the bank (i.e. the seller, S) and n realtors (i.e. the buyers, B) who participate in the foreclosure sale. The judgment value of the house (i.e. the balance of the mortgage) is denoted as v_J. The foreclosure auction is modelled as a (button) English auction as in Milgrom and Weber (1982), with both the bank and the realtors bidding in the auction.

The bid by the bank can be interpreted as a hidden reserve price. The auction website expedites bidding by allowing the participants to employ automatic bidding agents. The bidders provide their agents the maximum price they are willing to pay (their *dropout* price), and the agent then bids on their behalf. These proxy bids can be updated at any time.[4]

The key difference from a standard English auction is that the proceeding of the foreclosure auction up to the judgment amount goes to the bank, anything above the judgment amount goes to the original owner. This effectively turns the bank into a seller for prices below and into a buyer for prices above the judgment amount.

The winner pays the auction price p. If the price exceeds the judgment value, $p \geq v_J$, then the bank gets v_J and the owner pockets the difference $p - v_J$. If the price is below the judgment value, $p < v_J$, then the banks gets p and the owner gets nothing. The property is transferred to a realtor only if a realtor wins; otherwise, the bank keeps the property. It follow that if the bank wins the auction, it effectively pays the auction price to itself, so in reality no money changes hands in that case. But if a realtor wins, then there is an actual money transfer, from the realtor to the bank and possibly the owner as well (if the auction price exceeds the judgment value).

As is usual, we model the foreclosure sale (auction) as a game of incomplete information. As is explained in the empirical section of the paper, banks and brokers buy houses for different purposes: banks mostly sell the houses later on. Brokers typically renovate the property before reselling. Motivated by this, we make the following assumption concerning the information of the bank and the brokers. First, we assume that the i's realtor idiosyncratic signal, denoted as X_B^i, only concerns its renovation value added to the house. Second, we assume that the bank's signal X_S concerns the baseline resale value of the house. The signals X_B^i and X_S will be sometimes referred to as buyers' and seller's *types*. Their realizations will be denoted as x_B^i and x_S, respectively.

The bank is assumed to be the informed party. Its signal X_S is normalized to equal the expected value of the house in the market, so the seller's valuation is

$$u_S(x_S) = x_S.$$

[4]Such proxy bidding makes the button model even more applicable here, as it alleviates the need to model difficult features such as e.g. jump bidding that may be present in the traditional open auctions.

The realtors do not observe X_S; they only privately observe their own signals X_B^i. The realtor's expected value of the house, given its own signal x_B and the seller's signal x_S, is denoted as $u_B(x_B, x_S)$.

We make the following assumptions concerning the expected valuations of the realtors.

Assumption 1 (Buyer valuations)**.** *The buyer's expected valuation is differentiable and strictly increasing in own signal x_B^i, and nondecreasing in the bank's signal x_S,*

$$\frac{\partial u_B(x_B, x_S)}{\partial x_B} > 0, \quad \frac{\partial u_B(x_B, x_S)}{\partial x_S} \geq 0$$

This assumption ensures that a buyer's valuation of the house is increasing in its own signal x_B, and is non-decreasing in the seller's signal x_S. If u_B does not depend on x_S, we have a special case of *private values*. Otherwise, the valuations are interdependent.

For the reasons that will be clear in the sequel, we normalize the buyer signals so that the value conditional on winning the auction is equal to the signal,

$$u_B(x_B, x_B) = x_B. \tag{1}$$

This normalization is without loss of generality because Assumption 1 ensures that $u_B(x_B, x_B)$ is continuous and strictly increasing in x_B.

We make the following assumptions regarding the distribution of the signals.

Assumption 2 (Signals)**.** *The bank's signal X_S is drawn from a distribution F_S supported on $\mathbb{R}_+$ and with density f_S continuous and positive on the support. The realtor signals X_B^i, $i = 1, ..., n$, are drawn from a (joint) distribution F_B, supported on $\mathbb{R}_+^n$, with density f_B continuous and positive on the support.*

We assume that the signals are independent.

Assumption 3 (Independence)**.** *The signals $X_B^1, ..., X_B^n, X_S$ are independently drawn from their respective distributions.*

This independence assumption is made to simplify the analysis of the game, by eliminating the need to consider adjustments that brokers would otherwise make to their proxy bids following dropouts by other brokers. Under independence, we shall see that the information in the auction will be transmitted only from the bank to the brokers, following the bank's dropout from the auction. After that, the brokers would essentially have independent private values, and simply enter those values as their (updated) proxy bids, and there will be no updating from brokers' dropout prices.[5]

3 Independent Private Values

It is useful to first start with the special case of independent private values, since it provides some of the key insights without all the complexity of value interdependence. The independent private values setup is particularly useful to highlight the role of the judgment amount, below which the bank acts as a seller and above which the bank acts as a buyer.

Observe that it is a weakly dominant strategy for the realtor to choose its valuation as the drop out price, so

$$p_B(x_B) = x_B.$$

We allow the realtor values (signals) to be correlated. We make the following standard regularity assumption.

Assumption 4 (Virtual value monotonicity)**.** *The Myerson virtual value*

$$J_B(x_B) = x_B - \frac{1 - F_B(x_B)}{f_B(x_B)}$$

is strictly increasing.

With these preliminaries, the bank's dropout strategy is characterized in the proposition below. Refer to Figure 1.

Proposition 1 (Equilibrium)**.** *The bank's and realtor's bidding strategies are given by, respectively,*

$$p_S(x_S) = \begin{cases} J_B^{-1}(x_S) & \text{if } x_S \leq J_B(v_J), \\ v_J & \text{if } x_S \in [J_B(v_J), v_J], \\ x_S & \text{if } x_S \geq v_J. \end{cases} \qquad p_B(x_B) = x_B. \tag{2}$$

[5]Independence is also assumed in Jullien and Mariotti [2006], while Cai et al. [2007] and Lamy [2010] allow the buyer signals to be correlated, but still independent of the seller's signal.

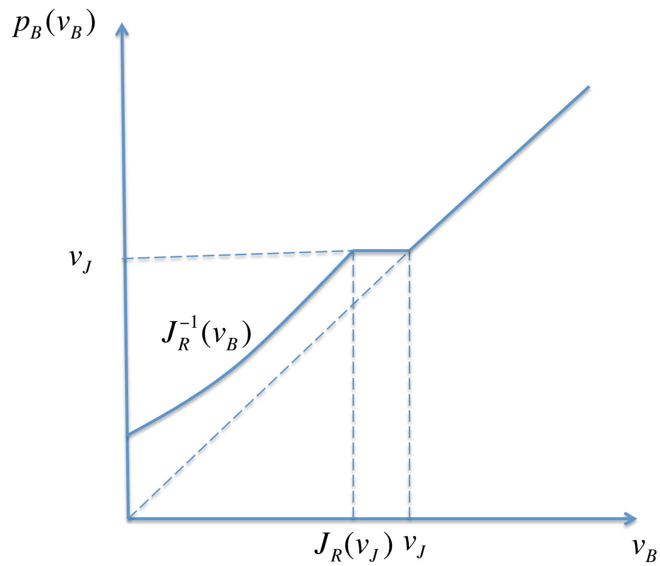

Figure 1: Equilibrium

Proof. If the bank decides set the reserve price below the judgment value, $p \leq v_J$, and if there is only one buyer ($n = 1$), then its expected profit is

$$\Pi_S^1(x_S, p) = x_S F_B(p) + p(1 - F_B(p)).$$

where the first term corresponds to the bank keeping the house if the realtor loses in the auction, and the second term corresponds to the transfer of the house from the bank to the realtor at price p. If there are multiple buyers ($n \geq 2$), its expected payoff is

$$\Pi_S^1(x_S, p) = x_S F_{(1)}(p) + p(F_{(2)}(p) - F_{(1)}(p)) + \int_p^\infty x_B f_{(2)}(x_B) dx_B, \tag{3}$$

where the last term corresponds to the price set by the second-highest realtor bid, when this value is above p.[6]

If, on the other hand, the bank decides to drop out at a price above the judgment value, $p > v_J$, then the expected payoff is given by

$$\Pi_S^2(x_S, p) = \begin{cases} x_S F_B(v_J) + v_J(1 - F_B(p)), & \text{if } n = 1, \\ x_S F_{(1)}(v_J) + v_J(1 - F_{(1)}(p)) + \int_{v_J}^p \big(x_S - (x_B - v_J)\big) f_{(1)}(x_B) dx_B, & \text{if } n \geq 2. \end{cases} \tag{4}$$

[6]Here and below we denote the cumulative distributions of the highest and second highest broker signal as $F_{(1)}$ and $F_{(2)}$ respectively.

From now on, for concreteness we restrict attention to $n \geq 2$; obvious modifications would be needed for $n = 1$. The first term applies in the event when the bank wins the house with the realtor dropping out at a price below the judgment value. In this case, the bank simply keeps the house, effectively paying the auction price to itself. The payoff in this case is simply x_S, and the probability of such an event is $F_{(1)}(v_J)$. The second term applies in the event when the realtor wins the house at a price above the judgment value, i.e. the bank drops out at a price $p < v_J$. In this case, the realtor pays p, but the bank only gets v_J, as the remainder goes to the owner. The probability of this event is $1 - F_{(1)}(v_J)$. Finally, the last term gives the expected payoff in the event when the bank wins the auction at a price x_B (the realtor's dropout price) above the judgment value. In this case, the bank needs to compensate the owner for the difference between the price and the judgment value, so the bank's payoff is then $x_S - (x_B - v_J)$.

With these formulas at hand, consider first the case when the bank's valuation is below v_J. Taking the derivative in (4), we get

$$\frac{\partial \Pi_S^2(x_S, p)}{\partial p} = (x_S - p) f_{(1)}(p), \quad p \geq v_J.$$

We can see that the dropout prices above v_J are on a downward-sloping arm of the the expected payoff functions and therefore will not be offered by a bank with $x_S \leq v_J$. It follows that for $x_S \leq v_J$, the problem of choosing an optimal dropout price amounts to maximizing the expected payoff in (3) subject to the constraint $p \leq v_J$. The Kuhn-Tucker first-order condition for this problem is

$$F_{(2)}(p) - F_{(1)}(p) - f_{(1)}(p)(p - x_S) \geq 0, \quad p \leq v_J, \tag{5}$$

with complementary slackness. Dividing the above equation through by $f_{(1)}(p)$, and noting that, under independence,

$$\frac{F_{(2)}(p) - F_{(1)}(p)}{f_{(1)}(p)} = \frac{1 - F_B(p)}{f_B(p)},$$

we see that if the constraint doesn't bind, then the optimal price is found from $J_B(p) = x_S$, so by the monotonicity of $J_B(\cdot)$, we get $p_S(x_S) = J_B^{-1}(x_S)$ iff $x_S \leq J_B(v_J)$. For $x_S \in [J_B(v_J), v_J]$, the constraint is binding, so $p_S(x_S) = v_J$. To complete the equilibrium characterization for $x_S > v_J$, consider again the first-order condition (5). For $x_S > v_J$, this first-order condition implies that it is optimal for the bank to bid its value, which completes the proof. □

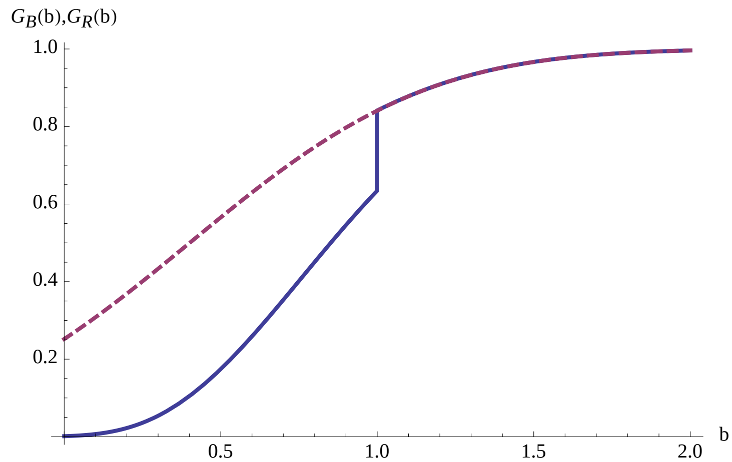

Figure 2: Computed equilibrium bid distributions for the bank ($G_S(\cdot)$; solid curve) and the realtor ($G_B(\cdot)$; dashed curve). The value distributions are specified as normal, with equal means $\mu_S = \mu_B = 0.4$ and standard deviation $\sigma_S = \sigma_R = 0.6$. The judgment value is $v_J = 1$. Observe the mass point at the judgement value in $G_S(\cdot)$.

Discussion As we mentioned before, the bank's equilibrium behavior is different depending on whether the bank's valuation is below or above the judgment value. The bank acts in a seller role in the former case, and in a buyer role in the latter. The most interesting feature of the equilibrium is the bunching region $[J_B(v_J), v_J]$. In this region, the bank's dropout prices are pooled at the judgment value (see Figure 1).

Why are the bank's dropout prices bunched at the judgment value? To get an intuition for this, note that the bank will only benefit from a dropout price above v_J if it keeps the house, i.e. wins the auction. Otherwise, if it sells the house, then even though the sale price would be higher than v_J, the bank stands to pocket only the judgment value v_J. So if the bank's valuation is *below* v_J, the bank would prefer to take v_J. This explains why there is a constraint $p \leq v_J$ in the bank's optimal pricing problem when $x_S \leq v_J$, which causes bunching at v_J for bank's values somewhat below v_J.

This bunching will cause a *mass point* at v_J in the distribution of the bank's dropout prices. Figure 2 illustrates this in an example with one buyer and normal distributions.

4 Common Values

We now consider the general environment with common values, where the bank is the informed party. As we shall see, an equilibrium still involves bunching at v_J, but there is also a novel feature: the seller's reserve price strategy is discontinuous and involves gaps around v_J. We begin by considering a setting that corresponds to $v_J \to \infty$, i.e. the standard English auction with an informed seller. We will refer to this setting as the *unconstrained equilibrium.*

4.1 Unconstrained equilibrium

Auctions in which the seller has information about the common value component have been considered in Jullien and Mariotti [2006], Cai et al. [2007] and Lamy [2010].[7] These papers characterize a separating equilibrium in strictly increasing, continuous and differentiable strategies. In the sequel, we shall refer to this equilibrium as an *unconstrained* equilibrium.

As some of our results rely on specific steps of their equilibrium construction, we now present these main steps in our context of the English auction.

We restrict attention to equilibria where the seller adopts an increasing and continuous equilibrium dropout strategy $p_S^*(x_S)$, with a differentiable inverse $X_S^*(p)$. Given our assumption that buyer signals are independent, only the seller's dropout price is relevant for information updating. Denote a buyer's strategy *before the seller has dropped out* as $p_B^*(x_B)$, with the inverse $X_B^*(p)$. As in Milgrom and Weber (1982), it is found by equating the object's expected value to the buyer assuming the seller drops out at p, to the price p:

$$u_B(X_B^*(p), X_S^*(p)) = p \tag{6}$$

Following the seller's dropout at a price $\tilde{p}$, a buyer's dropout strategy is simply $u_B(x_B, X_S(\tilde{p}))$ as the buyers will then have independent private values.

From now on, we assume $n \geq 2$, with a discussion of the case $n = 1$ relegated to a remark. If the seller with signal x_S enters a price p, while the buyers adopt a cutoff strategy $X_B^*(p)$,

[7] These papers consider the case of a publicly observable seller's reserve price in a second-price auction. However, our independence assumption ensures that the equilibrium is outcome equivalent.

the seller's expected profit will be

$$\Pi(p, x_S) = p(F_{(2)}(X_B^*(p)) - F_{(1)}(X_B^*(p))) + \int_{X_B(p)}^{\infty} u_B(x, X_S^*(p)) f_{(2)}(x) dx + x_S F_{(1)}(X_B(p)). \tag{7}$$

The first term on the r.h.s. of (7) is the expected revenue when the seller sells at the reserve p, which only occurs if there is a single buyer with signal above the cutoff $X_B(p)$. The second term is the expected revenue when the second-highest buyer signal is above the cutoff $X_B^*(p)$; in that case, the price paid to the seller is equal to $u_B(x, X_S^*(p))$, where x is the second-highest buyer signal. The last term is the seller's expected payoff if the seller keeps the house.

In equilibrium, the seller must choose his price $p = p_S^*(x_S)$ optimally, so we must have the following first-order condition,

$$\frac{\partial \Pi(p, X_S^*(p))}{\partial p} = 0, \tag{8}$$

which, taking into account (6) and after some algebra, yields

$$\frac{dX_B^*(p)}{dp} = \frac{\frac{1-F_B(X_B^*(p))}{f_B(X_B^*(p))} + \frac{dX_S^*(p)}{dp} \int_{X_B^*(p)}^{\infty} \frac{\partial u_B(x, X_S^*(p))}{\partial x_S} f_{(2)}(x) dx}{p - X_S^*(p)}. \tag{9}$$

If we now totally differentiate the marginal participating buyer's indifference condition (6),

$$u_B(X_B^*(p), X_S^*(p)) = p \implies \frac{\partial u_B}{\partial x_B} \frac{dX_B^*(p)}{dp} + \frac{\partial u_B}{\partial x_S} \frac{dX_S^*(p)}{dp} = 1, \tag{10}$$

and substitute $dX_B^*(p)/dp$ from (12), we obtain after some algebra the following two differential equations for $X_S^*(p)$ and $X_B^*(p)$:

$$\frac{dX_S^*(p)}{dp} = \frac{(J_B(X_B^*, X_S^*) - X_S^*)] f_{(1)}(X_B^*)}{\frac{\partial u_B}{\partial x_S}(u_B(X_B^*, X_S^*) - X_S^*) f_{(1)}(X_B^*) + \frac{\partial u_B}{\partial x_B} \int_{X_B^*}^{\infty} \frac{\partial u_B}{\partial x_S} f_{(2)}(x) dx}, \tag{11}$$

$$\frac{dX_B^*(p)}{dp} = \frac{F_{(2)}(X_B^*) - F_{(1)}(X_B^*) + \int_{X_B^*}^{\infty} \frac{\partial u_B}{\partial x_S} f_{(2)}(x) dx}{\frac{\partial u_B}{\partial x_S}(u_B(X_B^*, X_S^*) - X_S^*) f_{(1)}(X_B^*) + \frac{\partial u_B}{\partial x_B} \int_{X_B^*}^{\infty} \frac{\partial u_B}{\partial x_S} f_{(2)}(x) dxt}, \tag{12}$$

where the *Myerson virtual value* $J_B(x_B, x_S)$ is now defined as

$$J_B(x_B, x_S) \equiv u_B(x_B, x_S) - \frac{\partial u_B(x_B, x_S)}{\partial x_B} \frac{1 - F_B(x_B)}{f_B(x_B)}. \tag{13}$$

In parallel to Assumption 4 in the previous section, we assume that $J_B(x_B, x_S)$ is monotone is the buyer's signal.[8]

Assumption 5 (Virtual value monotonicity). *The function $J_B(x_B, x_S)$ is increasing in x_B.*

The following proposition describes the separating equilibrium in our model.

Proposition 2 (Unconstrained equilibrium: Cai et al. [2007] and Lamy [2010]). *There is a unique equilibrium in monotone differentiable strategies. The seller's inverse bidding (hidden reserve price) strategy $X_S^*(p)$ are given by the (unique) solutions to the differential equations* (11) *and* (12), *subject to the initial conditions $X_S^*(\underline{p}) = 0$ and $X_B^*(\underline{p}) = \underline{p}$. The lowest price offered by the seller $\underline{p}$ is given by $\underline{p} = p_S(0) = u_B^{(1)}(\underline{x}_B, 0)$, where $\underline{x}_B$ is the lowest buyer type that purchases with positive probability, given by the unique solution to $J_B(\underline{x}_B, 0) = 0$. For an out-of-equilibrium reserve price $p < \underline{p}$, buyers believe that the seller's type is* 0.

There is a noteworthy property of this separating equilibrium, in comparison with the scenario where there is no information asymmetry between the bank and and the brokers, i.e. if x_S is known to the brokers. In this *symmetric information* setup, the analysis in the previous section implies that the bank with valuation x_S will set the price so that the marginal buyer type willing to purchase at this price, $X_B^0(p)$ is found from the "marginal revenue equals cost" equation $J_B(X_B^0(p), x_S) - x_S = 0$. The price strategy itself is given by $p_S^0(x_S) = u_B(X_B^0(p), x_S)$. How does this price compare to the one with asymmetric information, $p_S^*(x_S)$? Proposition 2 shows that there is no distortion at the bottom, so that the two price are equal: $p_S^*(0) = p_S^0(0)$. The following corollary shows that asymmetric information leads to a *signalling premium* in the seller's price.

Corollary 1 (Signalling premium). *Under asymmetric information, the seller bids higher, $p_S^*(x_S) > p_S^0(x_S)$ for $x_S > 0$.*

Proof. For $x_S > 0$, monotonicity implies $dX_S^*(p)/dp > 0$. Going back the differential equation (11), this means that for $p = p_S^*(x_S)$, we must have $J_B(X_B^*(p), x_S) > x_S$, which, by the

[8] In the independent private values (IPV) case, $u_B(x_B, x_S) = x_B$ according to our normalization, and one can show $\frac{F_{(2)}(x_B) - F_{(1)}(x_B)}{f_{(1)}(x_B)} = \frac{1 - F_B(x_B)}{f_B(x_B)}$. So $J_B(x_B, x_S)$ becomes the usual Myerson virtual value as in the previous section.

monotonicity of $J_B(x_B, x_S)$ in x_B, implies $X_B^*(p) > X_B^0(p)$. Since $u_B(X_B^0(p), X_S^0(p)) = p$ and $u_B(X_B^*(p), X_S^*(p)) = p$, with $u_B(x_B, x_S)$ being monotone increasing in both arguments (under common values), we must have

$$X_S^*(p) < X_S^0(p) \implies p_S^*(x_S) > p_S^0(x_S)$$

for $x_S > 0$. □

The signalling premium leads to welfare losses under asymmetric information. Consider, for simplicity, a single buyer. Our normalization $u_B(x_B, x_B) = x_B$ implies that it is efficient to transfer the object from the seller with valuation x_S to the buyer with valuation x_B if and only if $x_B > x_S$. Denote as $x_B(x_S)$ the minimal buyer type that will, in equilibrium, trade with the seller with valuation x_S. It is found from $u_B(x_B(x_S), x_S) = p(x_S)$. Under asymmetric information, this type is determined from $u_B(x_B^*(x_S), x_S) = p_S^*(x_S)$, while under symmetric information, it is determined from $u_B(x_B^0(x_S), x_S) = p_S^0(x_S)$. Since $p_S^*(x_S) > p_S^0(x_S)$ due to the signalling premium, we must have

$$x_B^*(x_S) > x_B^0(x_S) > x_S.$$

Thus, the trading boundary, already distorted even under symmetric information due to the market power of the seller, is distorted even further under asymmetric information.

Under independent private values, it is well known that the seller's optimal reserve price does not depend on the number of bidders n. With common values, it generally will, since n appears on the r.h.s. of the differential equations (11) and (12) describing the equilibrium. In a linear valuation model, Lamy [2010] shows that the effect of the number of bidders on the seller's price may be either positive or negative, depending on the seller's signal.[9] However, the effect is unambiguous if we compare $n = 1$ and $n > 1$.[10] Denote the seller's price in the auction with n buyers as $p_S(x_S, n)$.

Corollary 2 (The effect of n)**.** *The seller's price is the lowest when $n = 1$:*

$$n > 1 \implies p_S^*(x_S, n) < p_S^*(x_S, 1).$$

[9] By focusing on the linear model, Lamy [2010] qualifies the results initially obtained in Cai et al. [2007]. We are not aware of any general results of this sort.

[10] Neither Cai et al. [2007] nor Lamy [2010] consider the case of a single buyer.

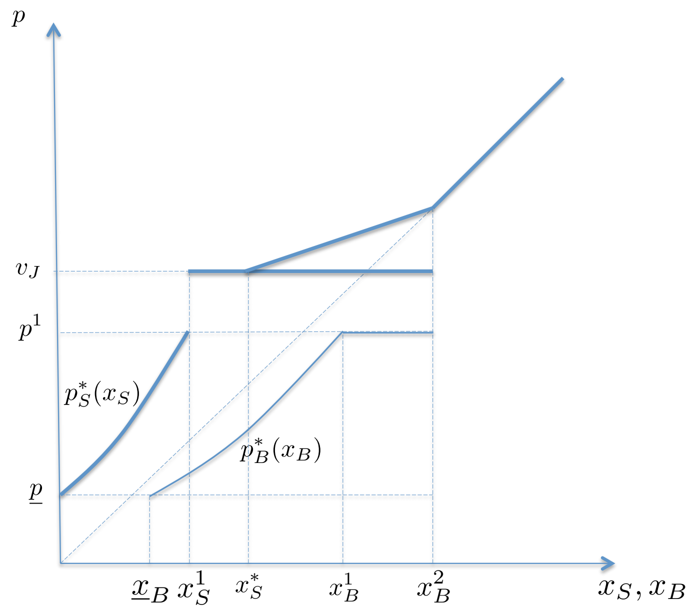

Figure 3: γ-Equilibrium with common values

Proof. Dividing (12) by equerryeq:sdifeq yields a single differential equation for $x_B(x_S)$. For $n = 1$, it is

$$x'_B(x_S, 1) = \frac{\partial u_B/\partial x_S}{\partial u_B/\partial x_B} \frac{1}{J_B(x_B, x_S) - x_S} \frac{1 - F_B(x_B)}{f_B(x_B)},$$

while $n > 1$, it is

$$x'_B(x_S, n) = \frac{\partial u_B/\partial x_S}{\partial u_B/\partial x_B} \frac{1}{J_B(x_B, x_S) - x_S} \Big(\frac{1 - F_B(x_B)}{f_B(x_B)} + \frac{\int_{x_B}^{\infty} \frac{\partial u_B}{\partial x_S} f_{(2)}(x)dx}{f_{(1)}(x_B)} \Big) > x'_B(x_S, 1).$$

Since $x_B(0, n) = x_B(0, 1)$,

$$x'_B(x_S, n) > x'_B(x_S, 1) \implies x_B(x_S, n) > x_B(x_S, 1) \quad \forall x_S > 0.$$

This, in turn, implies

$$p_S(x_S, n) = u_B(x_B(x_S, n), x_S) > u_B(x_B(x_S, 1), x_S) = p_S(x_S, 1).$$

□

4.2 Foreclosure auction equilibrium

Recall that in a judicial foreclosure, the bank is only entitled to the sale revenue up to v_J. As we have shown in the previous section, under IPV, this results in pooling of the seller's optimal price offers at v_J, while the offer below v_J are unaffected. In the present setting, however, simply "truncating" the seller's offer strategy at v_J, with pooled offers at v_J as in Figure 1, would create incentives for the seller to deviate and thus cannot result in an equilibrium. Specifically, the seller who would offer slightly below v_J, could instead signal a dramatically higher quality by "bunching in", i.e. deviating to $p = v_J$. Also, some sellers at the lower end of the pool, could do better by deviating slightly above, thus signaling higher quality and dramatically increasing the probability of sale.

In this section, we characterize a (semi) separating equilibrium where the bank's price strategy $p_S(x_S)$ coincides with the separating equilibrium strategy $p_S^*(x_S)$ as in Proposition 2 for $x_S \in [0, x_S^1]$, exhibits a jump to v_J at some type x_S^1. Above v_J, the bank randomizes between $p = v_J$ and the price that would keep the marginal buyer type the same as at v_J. Denote the minimal buyer type that drops our at $p = v_j$ as x_B^2. Then for the bank to be indifferent over any price in the randomization region $p \in [v_J, x_B^2]$, the bank should have the same "demand" $1 - F_B(x_B^2)^n$. So the "upper arm" of the equilibrium is given by

$$\overline{p}_S(x_S) = u_B(x_B^2, x_S).$$

For any price $p \in [v_J, x_B^2]$ the buyer with type x_B^2 is indifferent between dropping out or staying in. We denote the seller type where this upper arm departs from v_J as x_S^*; it is found uniquely from

$$u_B(x_B^2, x_S^*) = v_J.$$

See Figure 3.

The x_B^2-type buyer must be indifferent between winning the auction and paying the price v_J or staying out. Let $\gamma \in [0, 1]$ be the probability that the bank chooses v_J. Then the posterior distribution of the seller's types given $p = vJ$ is given by

$$f_S^*(x_S, \gamma) = \begin{cases} \frac{f_S(x_S)}{\gamma(F_S(x_B^2) - F_S(x_S^*)) + (1-\gamma)(F_S(x_S^*) - F_S(x_S^1))}, & x_S \in [x_S^1, x_S^*] \\ \\ \frac{\gamma f_S(x_S)}{\gamma(F_S(x_B^2) - F_S(x_S^*)) + (1-\gamma)(F_S(x_S^*) - F_S(x_S^1))}, & x_S \in [x_S^1, x_S^*] \end{cases}$$

The x_B^2-buyer indifference condition then takes the form

$$H(x_S^1, x_B^2, \gamma) \equiv \int_{x_S^1}^{x_B^2} u_B(x_B^2, x_S) f_S^*(x_S, \gamma) dx_S = v_J. \tag{14}$$

This condition implies that the buyer's cutoff $X_B(p) = x_B^2$ for the prices in the "upper" gap, $p \in (v_J, x_B^2)$, so the seller would face the same "demand" $1 - F_B(x_B^2)^n$ if he decided to set the reserve price in this gap. This ensures that, first, the sellers with $x_S \in [x_S^1, v_J]$ will not have an incentive to deviate to such a price, since doing so will not increase the probability of sale at v_J, and at the same time cannot yield a higher price because any excess revenue over v_J goes to the owner. Second, the seller types $x_S \in [v_J, x_B^2]$ will not have an incentive to deviate upwards either. As in the previous section, these sellers aim to bid as high as possible to deter buyer entry given that they strive to retain the object. But, as we have argued, ex-post individual rationality implies that they will not bid higher than their valuation x_S.[11]

The next condition specifies that the x_S^1-type seller is indifferent between dropping out at $p = p^1$ and $p = v_J$:

$$\Pi_S(x_S^1, p^1) = \Pi_S(x_S^1, v_J). \tag{15}$$

By a standard single-crossing argument, if the seller with $x_S = x_S^1$ weakly prefers price v_J to a price p^1, then the seller types $x_S \in (x_S^1, x_B^2]$ will in fact *strictly* prefer v_J to p^1. Taken together, the indifference conditions (14) and (15) imply that $p_S(x_S) = v_J$ for $x_S \in [x_S^1, x_B^2]$.

The bank will never choose to drop out at a price in the "gap" (p^1, v_J), provided that buyers will believe that the quality is not higher than what it would be, in expectation, if the bank instead waited and dropped out at v_J. Given such an out of equilibrium belief, which is reasonable, the bank will prefer to drop out at v_J instead: doing so will allow the bank to sell at a higher price if $x_S < v_J$, while will still not allow the bank to retain the house if $x_S \in [v_J, x_B^2]$. (The price will only go above p^1 if at least one broker has valuation $x_B > x_B^2$; such a broker will outbid the bank).

The bank with $x_S > x_B^2$ will be bidding against the brokers in a standard English auction, who will also have $x_B > x_B^2$ if the price goes higher than v_J). The bank will drop out at its value x_S, while brokers will drop out at prices that would make them indifferent given the bank dropping out at the same price. That is, the broker type $X_B(p)$ that drops out at p is given by the solution to $u_B(X_B(p), X_S(p)) = p$. Since $X_S(p) = p$ for $p > x_B^2$, our normalization

[11] Alternatively, one can assume that a buyer bids up to his expected utility, even if this drop out price is below the seller's publicly announced maximum bid.

$u_B(x_B, x_B) = x_B$ implies that $X_B(p) = p$ also. That is, for $p > x_B^2$, both the bank and the brokers will drop out at prices equal their signals.

So we define a class of randomized foreclosure equilibria, or γ-equilibria, as follows.

Definition 1 (Foreclosure equilibrium)**.** *For any randomization probability $\gamma \in [0, 1]$, the γ-equilibrium is defined as follows. The bank's dropout strategy $p_S(x_S)$ and the broker's dropout strategy when the bank hasn't dropped out, $p_B(x_B)$, are given respectively by*

$$p_S(x_S) = \begin{cases} p_S^*(x_S), & x_S < x_S^1, \\ v_J, & x_S \in [x_S^1, x_S^*], \\ \gamma\delta_{v_J} + (1-\gamma)\delta_{\overline{p}_S(x_S)}, & x_S \in [x_S^*, x_B^2], \\ x_S, & x_S > x_B^2. \end{cases}, \quad p_B(x_B) = \begin{cases} p_B^*(x_B), & x_B < x_B^1, \\ x_B^2, & x_B \in [x_B^1, x_B^2], \\ x_B, & x_B > x_B^2. \end{cases}$$

The broker's dropout strategy when the bank has dropped out at price p is given by $u_B(x_B, X_S(p))$ for $p \neq v_J$ (where $p_S(\cdot)$ is invertible), and for $p = v_J$, by

$$p_B(x_B, v_J) = \int_{x_S^1}^{x_B^2} u_B(x_B, x_S) f_S(x_S, \gamma) dx_S.$$

Refer to Figure 3. We say that the foreclosure equilibrium has the *separation property* if $x_S^1 > 0$. In this case, the seller types below x_S^1 will reveal themselves through their dropout decisions. If, on the other hand, $x_S^1 = 0$, then equilibrium involves bunching of all seller types $x_S \in [0, x_B^2]$.

Of course, the various cutoff types that appear in the equilibrium description depend on the randomization probability γ, $x_S^1(\gamma)$, $x_B^2(\gamma)$ etc. If $\gamma = 0$, so that all the weight is put on the upper arm $\overline{p}_S(x_S)$, then $p^1 = v_J$ and

$$x_S^1(0) = x_S^* = X_S^*(v_J), \quad x_B^2(0) = x_B^1 = X_B^*(v_J),$$

and the equilibrium involves a *continuous and strictly increasing* bank's strategy $p_S(x_S)$. There is no bunching at v_J.

This equilibrium for $\gamma = 0$ is directly derivable from the unconstrained equilibrium, as the buyer and seller cutoffs $x_S^1(0)$ and $x_B^2(0)$ are simply the values that correspond to the unconstrained equilibrium. See Figure 4. Thus, such an equilibrium always exists.[12]

[12]Here, we are implicitly assuming that the judgement value is not too low, $v_J > \underline{p}$.

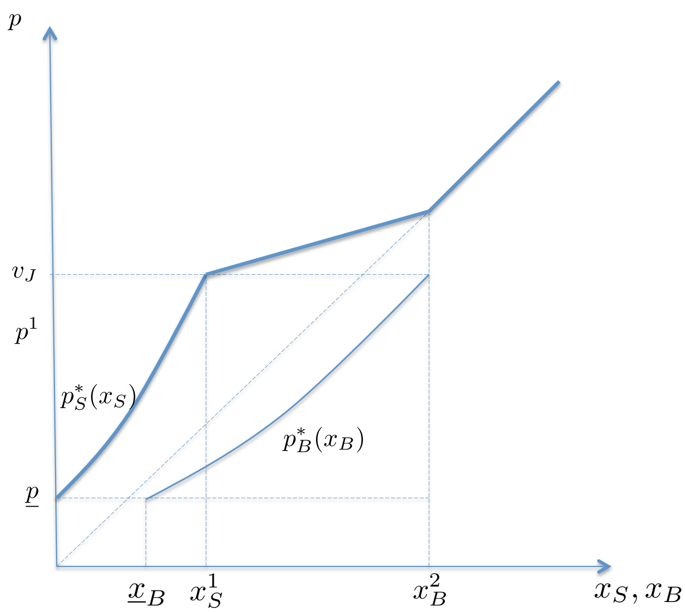

Figure 4: Equilibrium with common values: $\gamma = 1$.

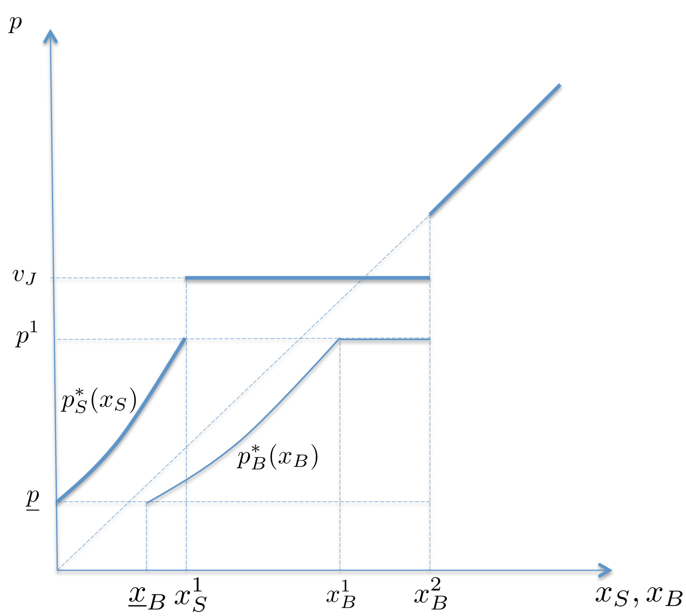

Figure 5: Equilibrium with common values: $\gamma = 0$.

If $\gamma = 1$, the equilibrium puts all the weight on the bunch, see Figure 5. With $\gamma = 1$, there is also a possibility that the bunch will extend all the way to the left, i.e. we have $x_S^1(0) = 0$, in which case the equilibrium is *not* semi-separating in the sense of our definition.

The next proposition establishes equilibrium existence and uniqueness of a semiseparating equilibrium.

Proposition 3 (Equilibrium existence and uniqueness)**.** *For any $\gamma \in [0,1]$, there exists a unique γ-equilibirum. Moreover, a $\overline{\gamma} \in (0,1]$ exists such that the equilibrium is semi-separating (i.e. $x_S^1(\gamma) > 0$) for $\gamma < \overline{\gamma}$ and semi-pooling (i.e. $x_S^1(\gamma) = 0$) for $\gamma \geq \overline{\gamma}$.*

Proof. The indifference condition (16) can be equivalently stated as

$$(\hat{p}(p^1) - x_S^1)(1 - F_{(1)}(x_B^1)) = (\hat{p}(v_J) - x_S^1)(1 - F_{(1)}(x_B^2)), \tag{16}$$

where $\hat{p}(p)$ denotes the equilibrium price received by the seller *conditional* on winning the auction with a reserve p. Given x_S^1 and $p_1 = p_S^*(x_S^1)$, the buyer's type that is indifferent between buying or not at p^1 is uniquely determined as $x_B^1 = X_B^*(p^1)$; recall that the buyer type that is indifferent at $p = v_J$ has been denoted as x_B^2.

The seller's indifference condition (16) defines x_B^2 as an implicit function of x_S^1. This function is denoted as $y_B(\cdot)$. The lower cutoff values are restricted between the lowest possible value $x_S = 0$, and the value $\hat{x}_S = X_S^*(v_J)$ that corresponds to the unconstrained equilibrium bid v_J. The buyer's indifference condition (14),

$$H(x_S^1, x_B^2, \gamma) = v_j,$$

also defines x_B^2 as an implicit function of x_S^1,

$$x_B^2 = z(x_S^1, \gamma).$$

Both mapping are defined on the domain $[0, \hat{x}_S]$.

The equilibrium cutoffs x_S^1 and x_B^2 are given by the intersection of the graphs of $y_B(\cdot)$ and $z_B(\cdot)$,

$$x_B^2 = y_B(x_S^1) = z_B(x_S^1, \gamma). \tag{17}$$

We now show that such an intersection to exist for all suffiently small $\gamma > 0$. Refer to Figure 6. We will first show the following monotonicity properties of $y_B(x)$ and $z_B(x, \gamma)$:

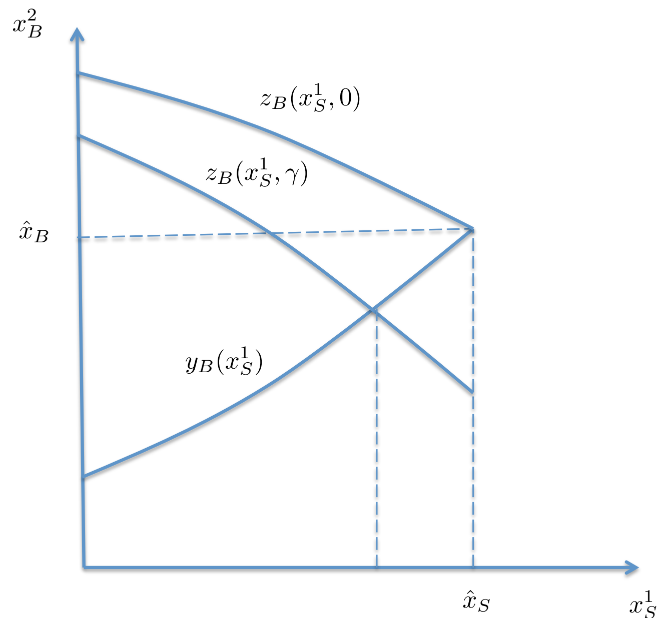

Figure 6: Functions $y_B(\cdot)$ and $z_B(\cdot, \gamma)$.

1. $y_B(x)$ is decreasing in x.

2. $z_B(x, \gamma)$ is increasing in x and decreasing in γ.

We first show that $y_B(\cdot)$ is an increasing function. The seller's indifference condition (15) can be re-written as

$$F_{(1)}(x_B^2) = 1 - \frac{\Pi_S(x_S^1)}{\hat{p}(v_J) - x_S^1}$$

where we denoted

$$\Pi_S(x_S^1) = (\hat{p}(p_S^*(x_S^1)) - x_S)(1 - F_{(1)}(x_B(p_S^*(x_S)))).$$

Next, we show that $\Pi_S(x_S^1)/(\hat{p}(v_J) - x_S^1)$ is increasing in x_S^1, which implies that x_B^2 is decreasing in x_S^1. The derivative of this function is

$$\frac{d}{dx_S^1} \frac{\Pi_S(x_S^1)}{\hat{p}(v_J) - x_S^1} = \frac{\Pi_S'(x_S^1)(\hat{p}(v_J) - x_S^1) + \Pi_S(x_S^1)}{(\hat{p}(v_J) - x_S^1)^2}$$

The envelope theorem implies $\Pi'_S(x_S^1) = -(1 - F_{(1)}(x_B^1))$. So the numerator is equal to

$$\begin{aligned}&\Pi_S(x_S^1) - (\hat{p}(v_J) - x_S^1)(1 - F_{(1)}(x_B^1))\\&= \Pi_S(x_S^1) - (\hat{p}(p_1) - x_S^1)(1 - F_{(1)}(x_B^1)) - (\hat{p}(v_J) - \hat{p}(p_1))(1 - F_B(x_B^1))\\&= -(\hat{p}(v_J) - p_1)(1 - F_{(1)}(x_B^1)) < 0\end{aligned}$$

where the inequality follows since $p_1 < v_J$ and $\hat{p}(\cdot)$ is a an increasing function. Hence, $y_B(x_B^1)$ is a decreasing function satisfying $y_B(\hat{x}_S^1) = x_B^2$.

The monotonicity of $z_B(x_S^1, \gamma)$ in x_S^1 and γ follows from the fact that $H(x_S^1, x_B^2, \gamma)$ defined in (14) is an increasing function in first two arguments, and is a decreasing function of γ. This is intuitively clear and can be shown by a direct calculation of the partial derivatives. When the equilibrium puts all the weight on the upper arm, i.e. $\gamma = 0$,

$$y(\hat{x}_S) = z(\hat{x}_S, 0).$$

As γ increases away from 0, the $z(\cdot, \gamma)$ curve shifts down, so by continuity, there is a (unique) intersection with the $y(\cdot)$ curve at least for sufficiently small γ. This implies that there is a unique semi-separating equilibrium for all sufficiently small γ. As γ continues to increase towards 1, the intersection point moves to the left. If

$$z_B(0, 1) > y_B(0),$$

then there is a (unique) intersection even if $\gamma = 0$, so that a γ-separating equilibrium will exist for *all* $\gamma \in [0, 1]$. Otherwise, there is a $\overline{\gamma} \in (0, 1)$ such that the equilibrium is semi-separating for $\gamma \in [0, \overline{\gamma})$ and is fully bunched all the way to 0 for $\gamma \in [\overline{\gamma}, 1]$. □

5 Empirical Predictions

Regardless of the environment, our model predicts *bunching* of seller bids at the judgement value. Denoting the distribution of seller reserve prices as $G_S(\cdot)$, we therefore have the following testable hypothesis.

Hypothesis 1 (Bunching at v_J)**.** *The distribution $G_S(p)$ has an atom at $p = v_J$,*

$$\lim_{p \uparrow v_J} G_S(p) < G_S(v_J).$$

Next, we can exploit the equilibrium prediction that, if there is adverse selection, i.e. the seller's signal affects buyer valuations, the reserve price $p_S(x_S)$ jumps from $p^1 < v_J$ to v_J. This leads to the following testable prediction.

Hypothesis 2 (Gaps under common values)**.** *If*

$$\frac{\partial u_B}{\partial x_S} > 0,$$

then the distribution $G_S(p)$ puts 0 probability mass on price intervals (p^1, v_J) and (v_J, x_B^2), i.e. it has "gaps" below v_J and above v_J. If, on the other hand, the values are private,

$$\frac{\partial u_B}{\partial x_S} = 0,$$

then the distribution $G_S(p)$ has a positive density at any price $p \in [\underline{p}, \infty) \backslash \{v_J\}$.

However, one should not expect gaps if there is heterogeneity with respect to common values, as one certainly would expect in reality. If the sales of some of the houses are characterized by common value, whereas for others the auction is essentially an independent private values auction, then the PV auction will fill out the gaps.

But heterogeneity with respect to adverse selection does have empirically testable implications. Take the simplest example, in which there are two types of houses: "independent private values houses" with $u_B(x_B, x_S) = x_B$ and "adverse selection houses" with $u_B(x_B, x_S) \neq x_B$. This is illustrated in Figure 7. Denote the lower bound of the lower gap by $p_1 = p_S(x_S^1)$ and let $p_2 = x_B^2$. For bank's prices below the gap for adverse selection houses ($p_S < p_1$), we will observe a mixture of IPV and of adverse selection houses. The probability of sale for such prices is the average of the IPV and the adverse selection probability of sale. In the gap ($p_S \in (p_1, v_J)$), we only observe independent private value. Hence, there will be an increase of the probability of sale. For $p_S = v_J$, we again observe both IPV and adverse selection houses, hence a sharp drop in the probability of sale just below $p_S = v_J$. Then again a sharp increase of the probability of sale just above $p_S = v_J$, since this in the interval (v_J, p_2) more weight is put on IPV houses since the adverse selection houses appear only when the upper "arm" is played, i.e. with probability γ in our equilibrium. One should not expect a sharp change at p_2, since for $p_S > p_2$ the probability of sale is the same for IPV and for adverse selection houses. The reason that $1 - F_{(1)}(X_B(p_S))) = 1 - F_{(1)}(p_S)$ is that for $p_S > p_2$, one has $X_S(p_S) = p_S$.

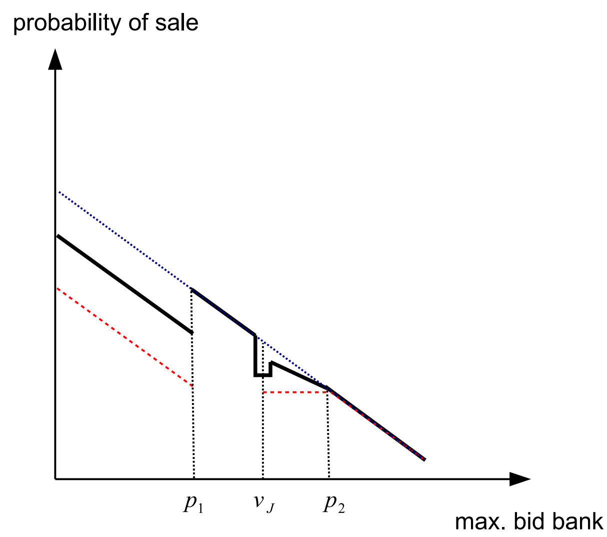

Figure 7: Probability of sale as a function of the bank's public maximum bid for independent private values houses (dotted, blue), adverse selection houses (red, dashed), and a mixture of both types of houses (black, solid).

Note that Figure 7 shows an extreme example: there are only two types of properties, those with strong adverse selection and those without any adverse selection. In reality, one would expect that there are more than two types of properties, that there are different strengths of adverse selection and hence gaps with different sizes. This will smooth out Figure 7, but we should still expect that the probability of sale increases in the bank's maximum bid at some prices slightly below the judgment amount and slightly above the judgment amount.

6 Data

The Clerk & Comptroller's auction website provides service for sales on the foreclosed properties in Palm Beach county, Florida, US. The website provides a platform for the banks (plaintiff, to whom property owners hold liability) and potential buyers (mosty realtors), to meet in this peculiar marketplace. The ClerkAuction conducts foreclosure sales on all business days, which provides a great deal of data on these sales.

We collected data on foreclosure sales from the website between January 21, 2010 and November 27, 2013. Our data record all transaction details on these sales, including winning bid, winner identities, and judgment values.

Our dataset contains 43,015 auctions with a total judgment amount of $13.3bn. The sum of winning bids is $3.3bn. Table 1 reports the summary statistics for main variables. The variable *bank winning* indicates that 84% of auctions under study ended up having properties transferred to bank's ownership.

Table 1: Summary statistics

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
bank winning	0.83	0.37	0	1
number of realtors	2.14	1.56	0	14
Variables with original scales				
winning bid	76,150.47	181,014.49	100.00	15,800,100.00
judgment amount	308,740.00	1,308,200.93	135.00	121,296,126.62
Variables normalized by judgment amount				
winning bid	0.31	1.53	2.24e-06	249.63

We now turn to empirical tests of our hypotheses. Figure 8 shows a graph with the empirical cumulative distribution of bids normalized by the judgment value. Observe the similarity in shape of the curves in Figures 2 and 8. In both there is bunching of the bank's bids at the judgment value. Note that for the numerical example in Figure 2 we assumed that the bank's and the realtor's distributions of valuations are the same, hence the overlap for bids above the judgment value. However, this does not necessarily have to hold; indeed Figure 8 suggests that this is not the case empirically.

Next, we plot the probability of sale as a function of the bank's public maximum bid (Figure 9). The most striking feature of the graph is that the probability of sale increases with the bank's reserve (i.e. maximum bid) just before and just after the judgment value.

This is exactly what theory predicts in case that there is heterogeneity in terms of adverse selection (see Figure 7). Further, observe that there is no gap below or above the judgment amount. This suggests that for some houses, adverse selection plays no role and one basically has an independent private value auction. For other auctions, there is adverse selection.

Figure 9 smooths sale as a function of the bank's maximum bid under the assumption that there is no discontinuity. Even without assuming a discontinuity, the figure suggests that this

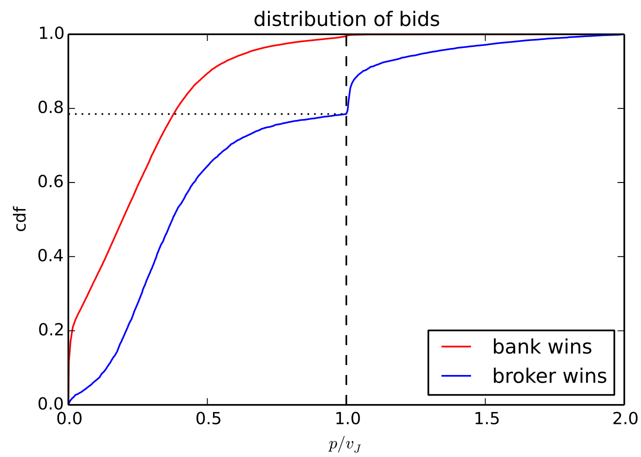

Figure 8: CDFs of bids (Normalized by judgment values). Bank wins in 35,904 auctions, broker wins in 6,830 auctions.

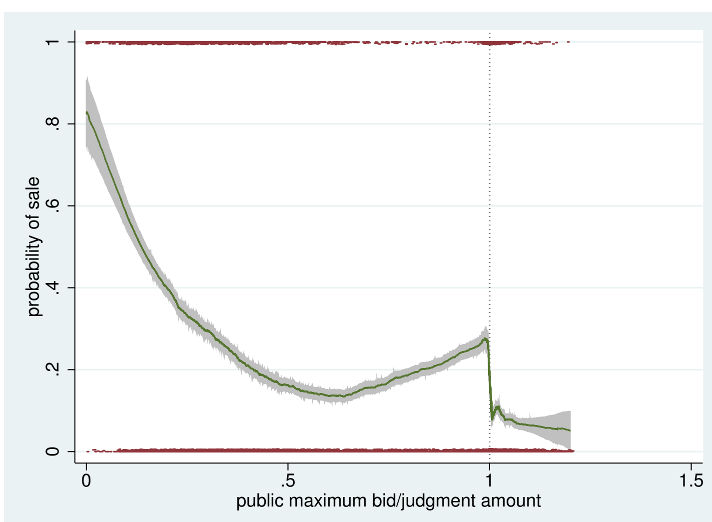

Figure 9: Probability of sale to a realtor as a function of the bank's maximum drop-out price (i.e. the bank's reserve price) (symmetric nearest neighbor smoothing). Dots denote individual observations (at the top if the house goes to a realtor, at the bottom if the bank keeps the house).

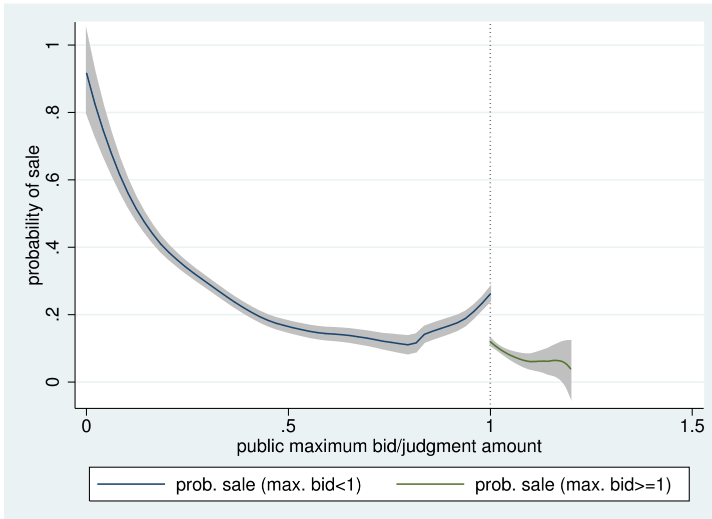

Figure 10: Probability of sale as a function of the bank's reserve price. Locally linear kernel regression with the data split at $p/v_J = 1$ (confidence interval: 95%, kernel: Epanechnikov, bandwith selection: rule-of-thumb (ROT) as described in Fan, J., and I. Gijbels. 1996. Local Polynomial Modelling and Its Applications. London: Chapman & Hall).

function is discontinuous at v_J. We also ran a locally linear kernel regression, splitting the data set at $p/v_J = 1$ as shown in Figure 10. Figure 11 shows the same regression as Figure 10, but based on data generated by a Monte Carlo simulation based on our model.

7 Securitization

There is an ongoing controversy about the securitization of mortgages in the U.S. Often, the claim is made that securitization was one of the main causes of the financial crisis. According to this view, securitization led to banks being to lax when handing out mortgages, knowing that holders of securitized assets and the Government Sponsored Enterprises Freddie Mac and Fannie Mae would ultimately pay the bill. An opposing view is that a lack of securitization caused the crisis: during the crisis, the issuing of securitized assets was drastically reduced, leading to less liquidity for banks, which forced banks to cut back on lending and hence exacerbating the crisis.

We first briefly describe the securitization of mortgages. First, the originating bank grants a mortgage to the home owner. In order to get liquidity, the originating bank sells the cash

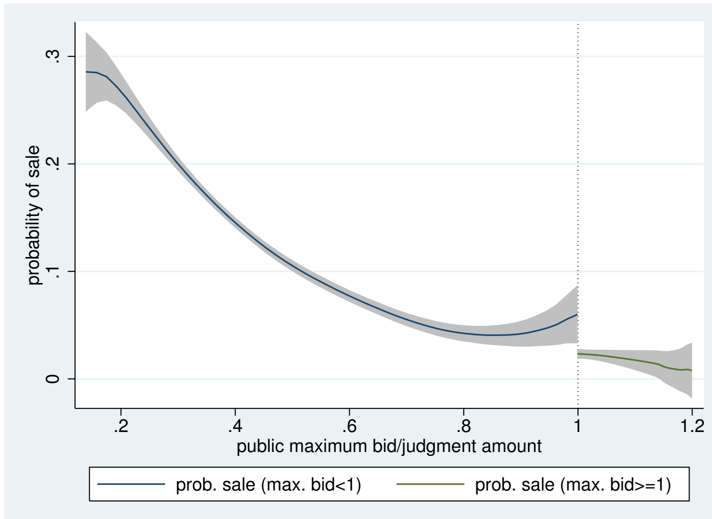

Figure 11: Estimation based on data generated by a Monte Carlo simulation, using the same estimation procedure as shown in Figure 10. Probability of sale as a function of the bank's reserve price. Locally linear kernel regression with the data split at $p/v_J = 1$ (confidence interval: 95%, kernel: Epanechnikov, bandwith selection: rule-of-thumb (ROT) as described in Fan, J., and I. Gijbels. 1996. Local Polynomial Modelling and Its Applications. London: Chapman & Hall).

flows from a pool of mortgages to a securitization agency, typically one of the Government Sponsored Enterprises Freddie Mac and Fannie Mae. The securitization agency splits the pool of assets into tranches and sells the tranches to investors on the capital market.

Since we have the name of the plaintiff in each foreclosure auction, we can categorize mortgages as securitized vs non-securitized. We use a simple classification rule, we classify a mortgage as securitized if the name of the plaintiff contains at least one of the following keywords: "TRUST", "ASSET BACKED", "ASSET-BACKED", "CERTIFICATE", "SECURITY", "SECURITIES", "HOLDER". This simple categorization does give false negatives (for some securitized mortgages none of the keywords shows up in the name of the plaintiff), but almost no false positives.

We report descriptive statistics for securitized versus non-securitized mortgages in Table 2.

Figures 12 and 13 show the probability of sale as a function of the bank's public maximum bid for securitized and non-securitized mortgages. One can see that for securitized mortgages

Table 2: Descriptive statistics for securitized and non-securitized mortgages.

	Price	Judgment value	$\frac{\text{Price}}{\text{Judgement value}}$	#
All auctions	76,150	308,740	0.313	43,015
	(181,014)	(1,308,201)	(1.532)	
Securitized	87,256	344,098	0.277	14,087
	(119,882)	(990,335)	(2.505)	
Non-securitized	70,742	291,522	0.330	28,928
	(204,047)	(1,437,471)	(0.658)	

the increase in the probability of sale just below and just above the judgment amount is much less pronounces. This is consistent with the theory that adverse selection plays less of a role for securitized mortgages, since the trustee of the mortgage pool is less likely to have an informational advantage over brokers than a local bank.

8 Non-Judicial Foreclosures

In this paper we have developed a theory of judicial foreclosures, i.e. foreclosures that are organized by a court. Roughly half of the states in the U.S. (including Florida) only allow judicial foreclosures. The other half of the states allow both judicial and non-judicial foreclosures. In a non-judicial foreclosure, the lender typically has the *power of sale* and can seize and sell the house without going through a court. The implication of this is that, under common values, the bank's information will become known to the realtor. The bank will market the property, and will allow prospective buyers to inspect it, thereby revealing x_S to them.

Note that comparing the utility of the original owner would be trivial: with non-judicial foreclosures, the original owner does not get anything, whereas with a judicial foreclosure, he may get something, so he is trivially better off.

Therefore, instead of the original owner's utility, we will compare overall welfare in judicial and non-judicial foreclosures. Note that we only need to consider the allocation rule, since transfers do not matter for welfare. An allocation rule consists of the probability $Q_S(\boldsymbol{x}_B, x_S)$ that the seller gets the house and the probability $Q_B^i(\boldsymbol{x}_B, x_S)$ that buyer i gets the house as a function of the seller's signal x_S and the vector of buyers' signals $\boldsymbol{x}_B = (x_B^i)_{i=1}^n$. Welfare is

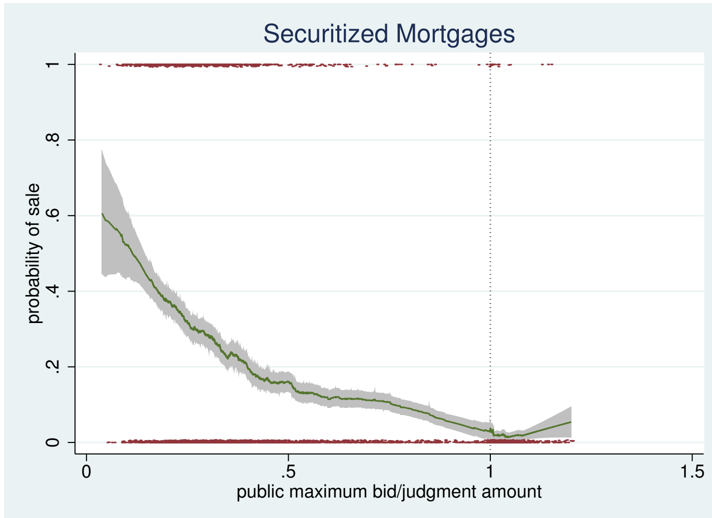

Figure 12: Probability of sale to a realtor as a function of the bank's maximum drop-out price (i.e. the bank's reserve price) (symmetric nearest neighbor smoothing) for securitized mortgages (bank wins in 2,671 auctions, broker wins in 577 auctions). Dots denote individual observations (at the top if the house goes to a realtor, at the bottom if the bank keeps the house).

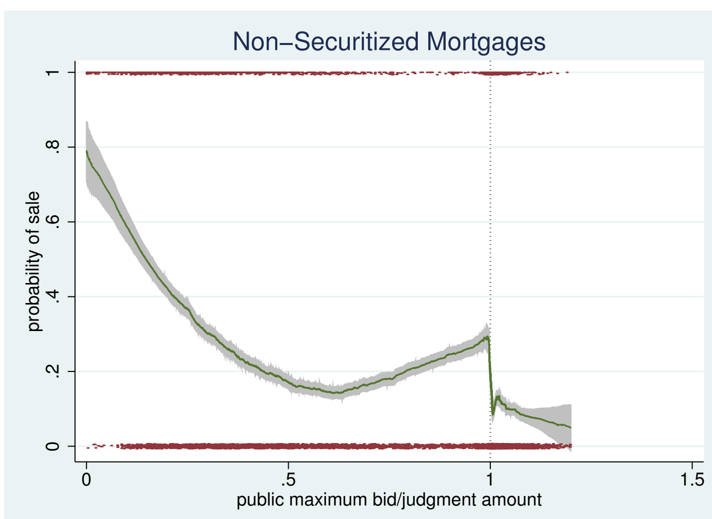

Figure 13: Probability of sale to a realtor as a function of the bank's maximum drop-out price (i.e. the bank's reserve price) (symmetric nearest neighbor smoothing) for non-securitized mortgages (bank wins in 7,724 auctions, broker wins in 1,644 auctions). Dots denote individual observations (at the top if the house goes to a realtor, at the bottom if the bank keeps the house).

then the expected sum of utilities for a given allocation rule:

$$\int_0^\infty ... \int_0^\infty \left[\sum_{i=1}^n Q_B^i(\boldsymbol{x}_B, x_S) u_B(x_B^i, x_S) + Q_S(\boldsymbol{x}_B, x_S) u_S(x_S) \right] dF_B(x_B^1)...dF_B(x_B^n) dF_S(x_S) \tag{18}$$

Observe that $u_B(x_B, x_S) > u_S(x_S)$ iff $x_B > x_S$ since $u_B(x, x) = x$ and u_B and u_S are weakly increasing in their arguments. Therefore, (18) is maximized by giving the house to the bidder with the highest signal x. Formally, the first-best allocation rule is

$$Q_S^*(\boldsymbol{x}_B, x_S) = \begin{cases} 1 & \text{if } x_S > \max_i x_B^i, \\ 0 & \text{otherwise,} \end{cases}$$

and

$$Q_B^{i*}(\boldsymbol{x}_B, x_S) = \begin{cases} 1 & \text{if } Q_S^*(\boldsymbol{x}_B, x_S) = 0 \text{ and } x_B^i > x_B^j \text{ for all } j \neq i, \\ 0 & \text{otherwise.} \end{cases}$$

As usual, an arbitrary tie-breaking rule can be specified for the zero-probability event that two signals are exactly the same.

For a non-judicial foreclosure auction, we assume that the bank sells the house in a standard auction with the same buyers with the same valuations showing up as in a judicial foreclosure auction. However, the bank is able to transmit the information to the realtors directly, by advertising the property and allowing inspections. Thus the nonjudicial foreclosures will be described by independent private values model, with x_S directly revealed to the relators.

Independent Private Values In an independent private values setup, the bank sets the reserve price equal to $J_B^{-1}(x_S)$ for all values of x_S in a non-judicial forceclosure. Thus the marginal buyer's cutoff is also equal to $J_B^{-1}(x_S)$. In a judicial foreclosure, the marginal buyer type is given by $J_B^{-1}(x_S)$ for $x_S < J_B^{-1}(v_J)$ and is equal to x_S for $x_S > v_J$.

Figure 14 shows the boundaries of the different allocation rules for the one buyer case. In first-best the buyer gets the house, if the realization of signals is above the 45 degree line (dashed). For judicial foreclosures, the buyer gets the house above the dotted blue line. For non-judicial foreclosure, the buyer gets the house above the sold red line. It is straightforward to show that welfare is higher with judicial foreclosures than with non-judicial foreclosures, since the deadweight loss of monopoly (the area between the dashed and solid line for judicial, the area between the dashed and the dotted line for non-judicial foreclosures) is smaller.

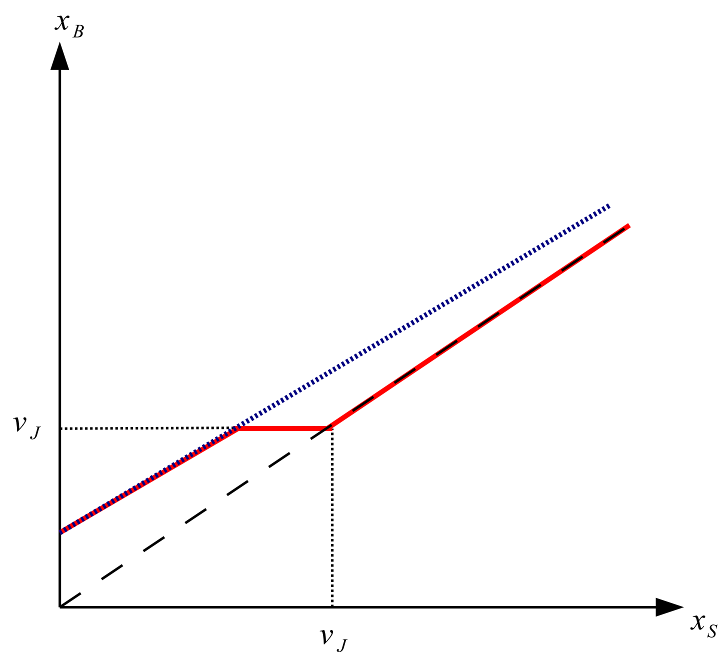

Figure 14: Judicial versus non-judicial foreclosure with independent private values. Lines separating the regions in which the seller and in which the buyer gets the house for first-best allocation (black dashed 45 degree line), for judicial foreclosure (solid red), and non-judicial foreclosure (blue dotted).

Common Values With adverse selection, the situation is more complicated as illustrated in Figure 15 for the one buyer case. The blue dotted line corresponds to the non-judicial foreclosure and comes from the solution under private values, where the realtor knows x_S. The martial buyer type with whom the x_S-type bank will trade is founds at the solution to the "marginal revenue equals cost" equation,

$$J_B(x_B^{nonjud}(x_S), x_S) = x_S.$$

The red solid line is the allocation rule for the judicial foreclosure implied by the seller's pricing behavior derived in our paper, i.e. $X_B(p_S(x_S))$. Observe that, due to the signalling premium, the solid line is above the dotted line for $x_S < x_B^2$. However, since the judicial auction is fully efficient for $x_S > x_B^2$, the solid line is below the dotted line for $x_S > x_B^2$. Hence, it is ambiguous whether the welfare would be larger or smaller for non-judicial foreclosures. The answer to this question would involve estimating a structural model of the foreclosure auction. This is left for future work.

It should be noted that we are ignoring any possible differences in administrative costs for judicial and non-judicial foreclosures. A full welfare analysis would have to take account such differences as well.

9 Conclusions

We develop a novel theory of foreclosure auctions. Our theory has the following main empirically testable predictions: (i) that banks' bids are bunched at the judgment amount, (ii) if all auctions observed exhibit a common value component, there are gaps in banks' bids just above and just below the judgment amount, (iii) if there are both independent private values and common value component auctions, there will be no gaps, but non-monotonicity of the probability of sale in the reserve (the probability of sale increases with the reserve just below and just above the judgment amount). Using a novel data set, we show that predictions (i) and (iii), but not (ii) are consistent with the data. This can be interpreted as both independent private values and common value component auctions showing up in the data set. Further, the data is consistent with the claim that adverse selection plays less of a role for securitized than for non-securitized mortgages. This is consistent with the idea that local banks with

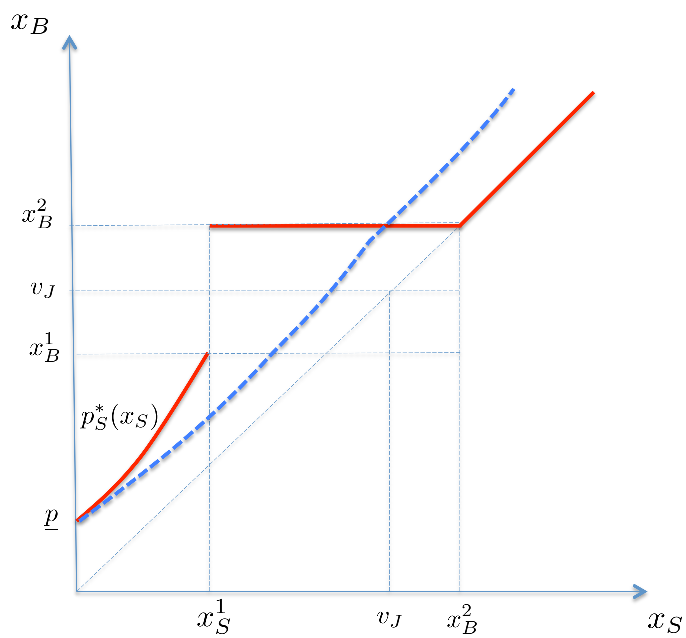

Figure 15: Judicial versus non-judicial foreclosure with a common value component. Lines separating the regions in which the seller and in which the buyer gets the house for first-best allocation (black dashed 45 degree line), for judicial foreclosure (solid red), and non-judicial foreclosure (blue dotted).

non-securitized mortgages have better information about the common value component than non-local banks who act as trustees for pools of securitized mortgages. Further, we show that judicial foreclosures generate higher welfare than non-judicial foreclosures in an independent private values setup. A welfare comparison between judicial and non-judicial foreclosures with a common value component is left for future work.

References

Hongbin Cai, John Riley, and Lixin Ye. Reserve price signaling. *Journal of Economic Theory*, 135(1):253–268, 2007.

Bruno Jullien and Thomas Mariotti. Auction and the informed seller problem. *Games and Economic Behavior*, 56(2):225–258, 2006.

Laurent Lamy. Corrigendum to ?reserve price signaling?[j. econ. theory 135 (1)(2007) 253–268]. *Journal of Economic Theory*, 145(6):2498–2504, 2010.