The Effect of Leverage on Bidding Behavior: Theory and Evidence from the FCC Auctions[†]

By

Matthew J. Clayton[*]

And

S.Abraham Ravid[**]

Current Version: December 1999

[†] We thank Ron Harstad for many comments and extremely helpful discussions concerning the FCC auctions. We thank Yacov Amihud Kyle Bagwell, Peter DeMarzo, Michael Fishman, Laurie Simon Hodrick, David Hirshleifer, Ken Kavajecz, Vojislav Maksimovic, Joshua Rosenberg, Matt Spiegel, seminar participants at the SFS and University of Texas at Austin Corporate Finance Conference, the AFA meetings, New York 1999, Rutgers University and New York University for many helpful comments and suggestions. We thank Bob Ewalt for dedicated research assistance. The usual disclaimer applies.
[*] Department of Finance, Stern School of Business, New York University, 44 West Fourth Street, New York, NY 10012-1126. e-mail: mclayton@stern.nyu.edu
[**] Department of Finance, Faculty of Management, Rutgers University, Newark, New Jersey and NYU.

Abstract

This paper investigates how firms' bidding behavior in various auctions is affected by capital structure. A theoretical model is developed where the first price sealed bid and the English auction are examined. We find as debt levels increase, firms tend to decrease their bids. The lower bids give the competition incentives to decrease their bid as well. These results are then investigated empirically using the recent FCC spectrum auctions. Consistent with the theoretical model, larger debt levels of the bidding firm and the competition tend to lead to lower bids. Additional determinants of bidding behavior in these auctions are also analyzed.

The Effect of Leverage on Bidding Behavior: Theory and Evidence form the FCC Auctions

A growing body of literature has been examining the interactions of production and financial decisions. There have been two theoretical approaches to the issue. One approach seeks to find the link between production and financial decisions in taxes and in bankruptcy states. Papers written by Hite (1978), DeAngelo and Masulis (1980), Dotan and Ravid (1985) and Dammon and Senbet (1988) demonstrate that investment and financing decisions jointly determine the expected tax liability and the expected bankruptcy cost paid by firms.

The alternative approach is to view leverage as a strategic variable, affecting firm production choices. Jensen and Meckling (1976) and Myers (1977), and later Brander and Lewis (1986), Maksimovic (1988), Titman (1984) Clayton (1999) and others suggest that debt can affect the quantity produced in oligopoly settings and that it can also impact decisions such as entry and investments. More recently, Showalter (1995) and Dasgupta and Titman (1998) have examined how debt affects price setting in oligopoly models. While the strategic approach seems to be supported by some recent empirical evidence (see Chevalier (1995a, 1995b) and Phillips (1995)), there may be other explanations for these empirical findings (see Ravid (1999))[1].

The impact of debt on the firm's real decisions should be most pronounced for short-term behavior, where debt restructuring is less likely. Our paper discusses a particular type of short run production interaction, namely the bidding behavior of firms in auctions. We first demonstrate that under some reasonable assumptions, levered firms will tend to under-bid (bid a lower price) compared to unlevered firms. These results are robust to some common auction designs, which broadly resemble the recent Federal Communication Commission (FCC) spectrum auctions. We investigate these auctions empirically, and find that the behavior predicted by the theory is consistent with firm bidding strategies in these auctions.

The rest of the paper is organized as follows. Section 1 discusses auction theory and leverage. The equilibrium-bidding behavior in the first price sealed bid auction is determined. In addition, the upper bound on the equilibrium bid in the English auction is determined. Section 2 presents the data and provides the empirical results from the FCC spectrum auction. Section 3 concludes.

---

[1] On a more basic level, Maksimovic and Kim (1990) document the impact of leverage on the production function in the airline industry. They demonstrate that debt causes inefficiencies, which is consistent with some agency models of conflicts between debt holders and shareholders.

1 Auction Theory

Auction design is very important in determining optimal strategies by bidders and sellers and revenue to sellers. In general, different types of auctions may yield different strategies and different revenues to sellers. This complicates the application of any analysis to real life auctions, which usually do not conform precisely to any theoretical model. Thus a major focus of the literature has been to compare various auction structures in terms of strategies and revenues to the seller. Vickrey (1961), under simplifying assumptions, shows that the open "English" and the first price sealed bid auctions provide equal expected revenue to the seller. Two important assumption in Vickery's (1961) work are that each bidder's valuation is an independent draw from an identical uniform distribution, and that all players are risk neutral. Myerson (1981) and Riley and Samuelson (1981) expand on Vickrey's results and demonstrate that, under less restrictive assumptions, several other auctions generate equivalent expected revenue to the seller. Thus, the revenue equivalence theorem asserts that the open "English", first price sealed bid, second price sealed bid, and descending Dutch auctions yield the same expected revenue to the seller. The assumption of risk neutrality is maintained. The bidders' valuations must be independent draws from an identical distribution; however, this distribution need not be uniform. This implies that when a seller wishes to allocate a good through an auction, the expected payment is the same under various auction mechanisms.

Various authors provide frameworks that relax the assumptions of the revenue equivalence theorem, which seems to indicate that under realistic settings auction design may still matter. Holt (1980), Riley and Samuelson (1981), Maskin and Riley (1984) and Milgrom and Weber (1982) show that under various assumptions, revenue equivalence fails to hold. When risky debt is outstanding, revenue equivalence may thus fail, and thus we need to examine several auction structures which resemble the complex FCC auction design.

The FCC used an innovative auction form called a *simultaneous ascending auction*. The basic procedure involves putting several items up for auction simultaneously through a repeated sealed bid structure. In each round, participants submit sealed bids on one or more of the items. As long as one item receives a new high bid, the auction proceeds to the next round. When no new high bids are submitted, the auction ends and the items are each sold to the highest bidder at a price equal to the amount they bid. To this already complex auction form, the FCC added a multitude of complex rules from dynamic eligibility requirements, the ability to withdraw bids, and the possibility of a reserve price. Regarding the complexity of the auctions: McMillan, Rothschild, and Wilson (1997) [p. 429] say "The setting for the FCC auctions is far more complicated than any model yet, or ever likely to be, written down." Further more McAfee and McMillan (1996) [p. 171 - 172] state:

> The spectrum sale is more complicated than anything in auction theory. No theorem exists – or can be expected to develop – that specifies the optimal auction form.
>
> A lesson from this experience of theorists in policymaking is that the real value of the theory is in developing intuition. The role of theory, in any policy application, is to show how people behave in various circumstances, and to identify the tradeoffs involved in altering those circumstances. What theorists found to be the most useful in designing the auction and advising the bidders was not complicated models that try to capture a lot of reality at the cost of relying on special functional forms. Such theorizing fails to develop intuition, as it confounds the effects of functional forms with the essential elements of the model. Instead, a focused model that isolates a particular effect and assumes few or no special functional forms is more helpful in building understanding.

Clearly we can not attempt to model the auction in every detail. Instead we look at some basic auction models that resemble the FCC auctions, and discuss how leverage would affect bidding in these models. The *simultaneous ascending auction* the FCC used has elements of a first price sealed bid auction as well as elements of an English auction. The firms were required to submit sealed bids and upon completion of the auction, the firm with the highest bid won, and paid their bid. This is similar to a first price sealed bid auction. However, the bidding was completed in rounds. After every round the bids were announced and everyone was allowed to submit new bids. This is similar to an English auction. Thus, we proceed by examining how debt affects bids in both the standard first price sealed bid setting and the standard English auction setting.

We proceed by first laying out the basic assumptions about the bidders and the general setting that are maintained throughout the theory section on the paper. We then analyze the first price sealed bid auction, and conclude the theory by investigating the English auction. The subsequent sections contain empirical analysis of the FCC auctions and conclusions.

1.1 The General Setting

For simplicity, we assume one seller, and n bidding firms. The value of the object sold may be different for each bidder, but each bidder knows their own valuation. This is the private values assumption, which is one of two standard auction settings. The alternative assumption is common value. Under the common value framework, the value of the object is assumed to be the same to all bidders but it is unknown. Each bidder receives only a signal about the true value of the object. The common value model is typically used to account for uncertainty about the true value of the object. According to several sources, common value elements were less important for the FCC auctions (see later discussion) therefore, we omitted the discussion of such auctions from the text (we do discuss how uncertainty may affect the bidding strategy in the English auction section below). We also assume that all players are risk neutral, and firms bid to maximize their equity value.

The value to firm i (i =1, . . . , n) of acquiring the good, v_i, is distributed with a known probability distribution F_i. The value realization of each firm is assumed to be an independent draw from the above distribution. Prior to the bidding stage, each firm observes their own value, however, only the distributions of the competing firms' values are known. Firm i has debt outstanding with face value FV_i, which must be paid prior to shareholders receiving any payoff. The debt level of each firm is common knowledge. Each firm is assumed to have cash on hand, c_i. If a firm cannot pay debtholders in full then the shareholders' payoff is zero.

It is assumed throughout the paper that the debt of each firm is risky. To keep the exposition of the model as simple as possible, this risk is created through the assumption that $FV_i > c_i$. This means the if a firm does not win the auction it will default. The magnitude of the debt overhang is what affects the firms bidding. Thus, we define the debt overhang of firm i as $D_i = FV_i – c_i$, and we refer to this as the firms debt though out the theory section of the paper.

Alternatively we could assume that the firm's underlying assets have a random value, and with some positive probability the total value of the firm's assets will be less than the amount of debt outstanding. This assumption would lead to the same basic result (more risky debt leads to lower bids), however, the effects would be somewhat mitigated. The intuition is as follows: if the firm knows it will not be bankrupt it will bid as if D_i is zero. However, if the firm knows it will be bankrupt it would bid as below (less for larger D_i). If there is a probability distribution over possible D_i, so that the firm may or may not be bankrupt the optimal bid would take into account both possibilities and thus would be between the two bids and thus at least weakly decreasing in D_i. It is important to point out that this assumes the firm knows the value of the object, v_i, with certainty. For a discussion of random object value see section 1.4. Qualitatively this more complicated model does not alter the basic insight; i.e. that firms that bid to maximize equity value only consider profits conditional on being solvent. Thus, we proceed under the assumption that a firm which loses the auction will default.

In each auction firms compete though a bidding procedure. The strategy of firm i will be a bid, b_i (.), which is a function of the firm's own value, v_i, the firm's own debt D_i, the competing firms' debt D_j ($j \neq i$), and what the firm believes to be the distribution of the competing firms' values, $F_j(v_j)$ ($j \neq i$). The firm that wins the auction receives the good for a payment, p, determined by the auction mechanism. Throughout this paper it is assumed that firm i wins the auction and that the value of the object along with the cash on hand are sufficient to make the payment, p, i.e. $p < v_i + c_i$. In essence, this means that a firm will not default on the payment for the good. However, a firm can finance some of the payment if $p < c$.[2] Firm i thus receives profits of v_i - p, and all other firms receive zero profits from the auction. Firm i must pay off its debt, D_i, and its shareholders receive any residual profits.

[2] For example, if V = 100, p = 60 and c = 50, the firm can borrow the extra 10 to pay for the object.

Firm i's shareholders receive max{v_i-p-D_i, 0}. Since D_j>0 the shareholders of firm j ($j \neq i$) receive nothing.

We now determine the Nash equilibrium bidding strategies and try to assess the role of leverage in the process. Each firm's bid function is a best response to the competing firms' strategies. Thus, given the competing firms' bid functions, each firm chooses its bid to maximize the expected payoff to its shareholders. In equilibrium, no firm has an incentive to change its strategy. Let $\pi_i[b_i(v_i,D_i,D_j), b_j(v_j,D_j,D_i)]$ denote the expected payoff realized by the shareholders of firm i as a functions of the bidding strategies. The bid functions $\hat{b}_i(.)$ (i = 1,…,n) are equilibrium bid functions if for each firm i:

$$\pi_i[\hat{b}_i(.), \hat{b}_{-i}(.)] \geq \pi_i[b_i(.), \hat{b}_{-i}(.)]$$

for all possible $b_i(.)$. Note that $b_{-i}(.)$ in the above equation represents the bidding strategies of all firms except firm i.

1.2 First Price Sealed Bid Auction

As noted, the FCC auctions have elements of a first price sealed bid auction and an English auction. We will begin the analysis with the former mechanism, where it is also easiest to see the impact of debt. In a first price sealed bid auction, the firms submit their bids to the buyer simultaneously. The firm that submits the highest bid wins the auction and pays a price equal to their bid. If multiple firms submit equal bids, the winner is determined randomly with each of the high bidding firms having an equal chance of winning. The firm receives the value v_i, and is left with max {v_i - b_i - D_i, 0} to distribute to its shareholders. All other firms lose the auction and receive no additional profits. A strategy for firm i is a bid function $b_i(.)$ based on its own realized value, v_i, the debt levels of all the firms, D_i, and its prior belief of the distribution of the competing firms' values and bid functions. A Nash equilibrium is a bid function for each bidder, where each firm is maximizing the expected payoff to shareholders given the bid functions of the competing firms. The bid functions $\hat{b}_i(.)$are equilibrium bid functions if for all i

$$b_i \in \arg\max_b [\max(v_i - b_i + c_i - D_i, 0)]\Pr\{b_i > b_{-i}(.)\}$$

The intuition of this expression is straightforward - a bid function is optimal if the expected payoff from winning is maximized.

A firm will not want to bid above its valuation because if it does and wins it will make negative profits. In addition, if a firm bids above its valuation in a first price auction the shareholders are guaranteed a zero payoff. Moreover, if the firm submits a bid greater than or equal to its valuation of the good minus its debt ($b_i \geq v_i$-D_i), then if the firm wins the auction there will be no residual profit left for shareholders. In fact if $b_i>v_i-D_i$, then upon winning the auction, the firm won't have enough money to completely pay off the outstanding debt. For this reason, a firm that chooses a bid to maximize the expected payoff to shareholders will bid $b_i<v_i-D_i$. As the firm decreases its bid from $b_i=v_i-D_i+c_i$, the probability winning the auction decreases, but the payoff shareholders receive conditional on the firm winning increases. The firm will decrease its bid below v_i-D_i trading off these two effects until the expected payoff to shareholders is maximized given its value realization and the competitors' bidding strategies. We will now proceed to analyze the optimal strategies of the bidding firms.

For each firm define a random variable $w_i = v_i – D_i$, and the following relation:

Relation 1:

$$\arg\max_b[(w_i - b_i)\Pr\{b_i > b_{-i}(.)\}] \subset \arg\max_b[\max(w_i - b_i, 0)\Pr\{b_i > b_{-i}(.)\}]$$

The above statement indicates that any bid, which maximizes the shareholder's expected payoff if the firm wins and the shareholders do not have limited liability, also maximizes the shareholder's expected payoff under limited liability.[3] If we assume the values, w_i, are independent draws from an identical distribution then the following bids represent an equilibrium (see McAfee and McMillan 1987):

$$(1) \quad b_1^* = w_i - \frac{\int_{\underline{w}}^{w_i}[F(\xi)]^{n-1}d\xi}{[F(w_i)]^{n-1}}$$

where F is the cumulative distribution function of w. This will be true for symmetric bidders, i.e. if we assume that all values are independent draws from the same distribution, and all firms have the same amount of debt, i.e., for all i, D_i = **D**. From **Relation 1** and equation 1, the following bids represent an equilibrium:

$$(2) \quad b_i^* = v_i - D - \frac{\int_{\underline{v}}^{v_i}[F(\zeta)]^{n-1}d\zeta}{[F(v_i)]^{n-1}}$$

where F is the cumulative distribution function of v.

Proposition 1. *The Nash equilibrium bids, b_i, are decreasing in* ***D****.*

PROOF: Follows immediately from the first derivative of equation (2).

[3] We thank an anonymous referee for pointing out this result. This relation allows us to simplify the exposition of the symmetric private value case.

Proposition 2. *The expected high bid, and thus the expected payment to the seller, are decreasing in **D**.*

PROOF: Result follows from proposition 1

Proposition 3. *Each firms' expected profits increase in **D**.*

PROOF: Result follows from proposition 1

As we noted earlier, risky debt affects the bidding strategies of the firms in several ways. As the amount of debt, D, increases, the bidding functions of the firms decline. This decreases the expected revenue to the seller. This also increases the expected profits and the total value of the bidding firms. Assuming that debtholders pay a fair market value for the debt issued, any increase in profits accrues to shareholders.

In this section we have demonstrated that leverage induces firms to bid less aggressively in a first price sealed bid private value auction, i.e. they bid lower than unlevered firms, thereby transferring value from the seller to the shareholders of the bidding firms.

1.3 English Auction

In this section, we investigate the effect of debt on bidding behavior in an English auction setting. In the standard English auction, bidders are continuously allowed to submit higher bids for an item. Bidding remains open until no bidder is willing to submit a higher bid. The high bid wins, and pays their bid for the item. This framework is perhaps the closest abstract setting to the complex FCC auctions. We maintain all the assumptions about the players from above. The classic solution in such a setting, when capital structure is not considered, is that each bidder will continue to increase their bid by the minimum increment until bidding reaches their valuation. I.e., Each bidder i sets $b^*_i = v_i$, where b^*_i is the maximum bid player i is willing to submit.

We now examine how the existing leverage of a firm affects its behavior in the English auction. Our first observation is that the firm will clearly be willing to bid up to the point at which $v_i – b_i = D_i$. I.e. $b_i = v_i – D_i$. Another way to see this is that if the firm wins the auction with a bid of b_i, then the profits from the auction are $v_i – b_i$. If b_i is such that $v_i – b_i > D_i$, the profits are sufficient to pay off the debt holders and the equity holders receive $v_i – b_i - D_i$. If the firm loses the auction, the equity holders receive a zero payoff. Thus, it is always beneficial for the firm to choose a stopping rule $b^*_i \geq v_i – D_i$.

Proposition 4. *A stopping rule $b^*_i \in \{v_i - D_i, \infty]$ for all participants, constitutes a Nash equilibrium in the English auction.*

It is shown above why $v_i - D_i$ is the minimum stopping point a firm would choose. Note that equity receives a payoff of zero if the firm bids above $v_i - D_i$, and wins the auction. Equity also receives a payoff of zero the firm loses the auction, so the firm is indifferent between any stopping rule $b^*_i \geq v_i - D_i$.

Proposition 5. *The lower bound of the set of sustainable Nash equilibrium bids is decreasing in leverage.*

This follows immediately from examining the equilibrium bid interval in proposition 4. If a firm has larger debt, D_i, then the minimum equilibrium stopping point is at a lower bid, $v_i - D_i$.

Discussion

We have shown that in a simple, abstract setting, bidding will be lower for both English and first price sealed bid auctions. We now consider several complicating factors. The most notable is the cost to submit bids. If bidding is costly, bidders will have incentives to end the auction quickly in order to minimize the total costs of bidding. Daniel and Hirshleifer (1996) show that bidding costs can lead to jump bids to signal valuations, and decrease the number of steps in an English auction. In the absence of a signaling motive, the addition of bidding cost would only slightly affect the set of Nash equilibrium stopping bids determined in Proposition 4. The minimum possible equilibrium bid would now be $v_i - D_i$ minus the cost to submit a bid. With signaling, this would still be the minimum possible equilibrium bid, however, the firm would also take into account the signals received of other players valuations before deciding to submit another bid (even if the current bid level was below $v_i - D_i$ – {the cost to submit a bid}).

We have also assumed so far that the manger can submit bids with no personal cost, such as a cost of effort. If the bidding cost include a direct cost to the manager, then no bids above $v_i - D_i$ – {the cost to submit a bid} will ever be submitted, since the bidder incurs a cost and all benefits go to bondholders. To fully model the effects of an effort cost to management we would have to explicitly model the benefits management receives from winning the auction. The benefit is likely to come through either 1) promotion and increased salary based on the profitability of wining the auction for the firm (i.e. based on $v_i - D_i$, or 2) from an increase in value of stock or stock options that management has in the firm. The minimum bid that management would want to bid up to would be approximately $v_i - D_i$. The actual minimum stopping bid would be slightly lower and it would be based on the manager's cost to submit the bid relative to the benefit the manager receives when $v_i - D_i > 0$. In addition, and more importantly, submitting a bid above $v_i - D_i$ can no longer be an equilibrium strategy. For any bid above v_i - D_i management knows they will get no benefit if the firm wins but they pay a personal cost to submit the bid. Thus we have the following:

Proposition 6
If managers incur a personal cost in bidding, the highest bid they will be willing to submit will decline with leverage.

1.4 Uncertain Object Value

There are two classical effects of leverage on firm behavior, dating back to Jensen and Meckling (1976) and Myers (1977). The first is under-investment, in other words, shareholders do not care about states in which revenues only accrue to bond-holders. Thus if they must pay for the investment and they only receive a payoff if the firm is solvent they may turn down a project that has a positive NPV. The second effect is risk shifting, i.e. shareholders will tend to select riskier projects, since they reap a disproportional share of the benefits if the project succeeds, whereas bondholders bear most the costs if the project fails. When a firm decreases its bid it is under investing, and at the same time increasing the risk of the auction. The risk is increased, since with a lower bid the firm has a smaller probability of wining the auction, but if it wins it will realize a higher payoff. This assumes that the auction is a private value auction, i.e. the firm knows what value it places on the object.

If we assume that the true value of the object is unknown to the bidder, then there are two possible ways the bidder can increase the risk of the auction. The first would be to lower the bid as above. The second would be to raise the bid, thus increasing the probability of winning. At the same time, this exposes the firm to the risk of the underlying object's value. In such a case, higher bidding may create increased risk. Thus, our predictions are most applicable in settings where the main source of uncertainty is whether a bidder wins at a given price, rather than how much the object is worth (after conditioning on all the information available to bidders). It is extremely difficult to model the latter uncertainty in the private value case. In fact, we know of no such model. Uncertainty of object value is typically modeled in a common value framework. The consultants who designed the FCC auctions suggested that common value and affiliated value effects were not important in those auctions (we thank a referee for bring this to our attention, see Salant (1997)). However, if object value uncertainty exists, then leverage may lead to either higher or lower bids – the issue becomes an empirical question.

A second point is more general. Risk shifting is often made difficult by various bond covenants, especially for riskier companies (some of the firms in our sample were rated BBB and below). On the other hand, under-investment essentially cannot be stopped. There are no covenants that force companies to invest. Therefore it seems that it will be much easier to respond to under-investment incentives rather than to risk shifting incentives. Further, since in real life investment opportunities are usually not known at the time the debt is issued, pricing them out would be impossible. For these two reasons, one would expect the theoretical analysis above to be most applicable to the FCC auctions. However, again, what actually happens is an empirical issue.

2 Evidence from FCC spectrum auctions

It is common for interaction papers (see for example, Brander and Lewis (1986), Dotan and Ravid (1985), Dammon and Senbet (1988) Maksimovic (1988) or Clayton (1999)) to model a single firm or a small number of competitors (typically two), where each "firm" is essentially comprised of a single project. However, empirical testing of these models is generally in a more complex setting. Maksimovic and Kim (1990), Chevalier (1995a, 1995b), Phillips (1995) and others all use data from industries with a large number of competitors and a large number of projects.[4] Also, the effects we model are just one component of the numerous factors that determine firms' actions and reactions. However, the fact that the effects analyzed in our model are robust to different basic types of auctions gives us some confidence as to the applicability of the results. In order to test our conjectures empirically, we needed to find auctions with detailed information regarding bids and where competitors are publicly traded firms so that leverage can be estimated. We therefore chose the recent FCC auctions. [5]

We shall now briefly describe the FCC auctions analyzed in this section.[6] A more detailed description is provided in Appendix B. With the expansion of communications and the broadcast media in recent years, the government has begun auctioning off the airwaves. These airwaves had previously been given away, essentially free of charge, to radio and TV stations, telephone companies and others, complying with certain regulatory restrictions. There have been several spectrum auctions in recent years, employing reasonably complex rules.

The auction we are investigating offered for sale the important "Broadband" spectrum. Two blocks (A and B) of 30 MHz each, in 51 Metropolitan areas were open for bids (except for New York, Los Angeles, and Washington D.C. where only block B was auctioned). This produced a total of 99 blocks. In total these blocks cover the entire continental United States. Each geographical area had two incumbents, winners of previous auctions, each holding title to a 25 MHz band. A and B licenses thus

[4] See Porter (1995) for an example of empirical auction literature.

[5] An auction with costly bidding, such as in Daniel and Hirshleifer (1996), would result in bids closer to the empirical bids observed in the FCC auctions. However, Daniel and Hirshleifer's (1996) model is still a simplified version of a more complex reality. If we were to extend their model to our setting, the theoretical analysis would have been considerably more cumbersome.

[6] For a detailed analysis and assessment of these auctions see Cramton (1997)

allowed a third and a fourth competitor to enter, each receiving title to a 30 MHz band. This spectrum was intended for “personal communication”, which has a broad legal meaning, but is well suited for digital cellular communication, including fax and data transmission. The auction began on December 5, 1994 and ended on March 13, 1995 after 112 rounds. It raised 7.7 billion dollars for the government.

The auction proceeded in rounds as follows: in round 1, each firm submitted a sealed bid on any block (or blocks) they chose. These bids were then revealed and the high bid for each block was determined. The auction now proceeded to Round 2, where each firm could again submit a sealed bid for any block (or blocks) they wished. The bids were announced, and it was determined if any blocks had new high bids. If at least one block had a new high bid, then the auction continued to Round 3 where again firms could submit sealed bids for any block (or blocks).[7] The auction continued until a round occurred where no block received an increased bid. This mechanism was established because it was believed that there would be synergies between the blocks, which is consistent with our empirical results. The winning bidders essentially had to pay the amount they bid in cash (more specifically, there was an upfront payment which defined eligibility, 20% of the bid was due five business days after the auction closed and the rest when the license was formally awarded).[8,9]

We use the FCC auction to test the theory that the highest bid submitted by a company (not necessarily the winning bid) was affected by its own capital structure and the capital structure of the competing firms.[10] According to the theoretical models developed, we should expect the highest submitted bid of a firm to be decreasing both in its own debt level, as well as in the leverage of rival firms. In addition, we examine whether the FCC is correct in the hypothesis that the blocks have synergies. In particular, we investigate a specific possible synergy where the value of a block is higher if the firm owns a block in an adjacent area (although there may be other issues, which may determine the value of an area to a bidder, see Appendix B and see Cramton (1997)). If this synergy exists we would expect to see a firm increase the highest bid it submits for an area if it owns the rights in an adjacent area. We also use additional control variables.

[7] Each time the auction moved to a new round, the firms could submit higher bids for ANY block, not just blocks that received a new high bid in the last round.

[8] Licenses were typically awarded one to three months after the auction was concluded.

[9] In a later auction of C blocks, i.e., additional competitors and a different spectrum band, the winning bidders were only required to post a 10% down payment of the amount bid. In that auction, bidding reached stratospheric heights, and in 1997 several important bidders were on the verge of bankruptcy. The FCC had to come up with a plan, adopted with a narrow majority, to save the auction (see New York Times September 26th, 1997 p. D1). Auctions of later blocks (after block C) were being investigated in 1997 for collusion and fraud. In 1998 the mess was still being sorted out. The auctions of blocks A and B are thus the “cleanest” auctions to work with and closest to our theoretical model.

[10] Note that this multi-round FCC auction is essentially an open out cry auction, however, since sealed bids are submitted, there are elements of a first price sealed bid auction as well.

2.1 Data

The main source of data was the FCC web site (FCC.Gov) that lists all bids in all auctions. For each block for which a firm submitted a bid, we collected the final (highest) bid submitted by the company. Since the two blocks, A and B, were essentially identical, we only considered the highest bid between the two blocks for each company (some companies would quickly drop out of bidding for block A but continue bidding for block B in the same Metropolitan area).[11]

Thirty companies participated in the bidding for the various Metropolitan areas. Some companies were limited partnerships, others were privately held.[12] For other companies we could find no additional identifying information. We were left with 14 companies, for which a complete data set could be assembled, leading to 150 company-bid pairs.[13] The number of company-bid pairs is relatively large, because we have information about the largest and generally most active companies.[14] Company information was obtained from Compustat for the yearend 1994, which is approximately when the auction took place.

For leverage, we used book and market value debt-equity ratios. It is important to note, that while the companies in our sample are indeed large and publicly traded they fit our characterization (i.e., they have risky debt). While one company was rated AAA, all others were rated lower, down to BBB-. At that level, the cumulative default probability over 10 years is close to 3%, see Altman, Cooke, and Kishore (1998).

The market value ratios were computed using stock prices as of December 31st 1994. We adjusted bond prices as follows: we used the Warga Lehman Brothers' fixed income data base to obtain market values for all bonds available for each company. We adjusted the book value of the bonds for which we had information to reflect market values. We then adjusted the rest of the debt listed for the company by the same average percentage. For example, if a company has two bonds, of equal book value, and only one bond is listed at a price of 102, we increase the price of both bonds by 2% over the book values. We also used interest coverage, bond ratings, and Altman's Z ratio as alternative measures of default risk. For the bond ratings, we used both a variable which transforms each rating into a numerical count, as well as, several variations of dummy variables which divide the companies into more or less risky subsets. Altman's Z ratio has been used extensively to study the default risk of firms and we used as a proxy for the risk of bankruptcy. We also developed several

---

[11] No firm won both block A and B in the same Metropolitan area.

[12] For example, ALAACR was privately held by Craig McCaw.

[13] See Appendix A for a list of all companies in the auction. The most active bidder, Wireless Co. is a partnership of Sprint, Tele-Communications, Cox Cable and Comcast. We formed a weighted average for all company data based upon the weights in the partnership (40%, 20%, 20%, 20% respectively).

[14] Note, however, that our theory relates to bidding behavior and therefore is applicable to each bid by each company rather than to total bidding behavior.

variables to directly test our theory on the effect of the competing firms' leverage on bids. We constructed two measures, a weighted average of the capital structures of all competitors in a specific market, and an equally weighted average. We calculated both market value and book value measures. We also calculated a value-weighted average of the interest coverage of competitors.

Additional Compustat data collected included sales and total assets. Since bidding strategies varied by firms (see Cramton (1997)) we also included dummy variables for some firms.

We constructed several additional variables to control for possible synergies, which may be present in holding licenses for adjacent areas. We created a dummy variable which receives a value of 1 if the company in question had won a license in an adjacent market in a previous round of the current (A and B block) auction and 0 otherwise. Another variable measured whether or not the company had licenses in the same area won in previous auctions. The FCC did not allow companies that had a strong presence (in terms of market share) in a market to bid for that same market during this auction. Namely, no company was allowed to hold more than 45 MHz in any Metropolitan area. Incumbent companies held 25 MHz already, and hence were ineligible to bid for an additional 30 MHz in the same Metropolitan area. However, firms with a "small" presence were not prohibited from bidding for a market. We also determined if companies had won earlier auctions for different wavelengths in adjacent areas.

Bids are also strongly influenced by the population of each area and the economic status. Our dependent variable is thus stated as the high bid in terms of dollars per capita.[15] Population information is listed in the FCC site for each market available. We used additional data out of Demographics USA (1997) which listed population and total disposable income in each metropolitan area. This information was used to calculate income per capita for the largest metropolitan area in each region.

2.2 Results

Our empirical test uses the highest bid per capita, that each firm submitted for a region as the dependent variable.[16] An OLS regression is used to ascertain whether leverage plays a role in determining the highest bid each firm is willing to submit for a particular metropolitan region. According to our theory, an increase in leverage should

[15] This is the common way bids are described by professionals and by participants. In fact, the up front payments and some rules were defined in terms of MHz pop which is similar to our definition.
[16] This bid was not necessarily the winning bid. If a firm did not win a market, we us the highest bid the firm submitted in that market.

cause a decrease in the high bid a firm submits in each region in which the firm actively participates. In addition, an increase in the leverage of the competition should also decrease the high bid the firm submits. Table 1 contains summary statistics that describe the data.

Basic Regression With Market Leverage Ratios

In our baseline regressions, we test to determine if leverage affects bidding behavior controlling for simple firm characteristics. We use the market debt equity ratio to represent leverage. We expect a negative coefficient on this variable to reflect lower bids with higher debt. We also use the average debt equity ratio of the competitors in each market as an independent variable. If the competition lowers their bids with higher debt, we would expect our optimal response to entail a lower bid as well. Thus, we expect the competitions' debt equity ratio to have a negative coefficient. For each metropolitan area we include the per capita income. We expect areas with a larger income to be more valuable, and thus elicit higher bids. To control for possible synergies between owning two adjacent metropolitan areas we include a dummy variable that equals one if the bidding firm wins an adjacent market in the current auction. In addition, to control for a possible interaction between the value of winning this license and already owning a license in the same area we include a dummy variable which equals one if the bidding firm already owns a incense in the current metropolitan area. We control for firm size by including either the long of firm sales, or the log of firm assets.

Results of our baseline regressions are in Table2. As expected, income per capita, and the adjacent dummy both have positive and significant coefficients in all regressions. This implies that firms bid more for a region with a higher per capita income, and also have higher bids in regions that are adjacent to regions in which they have won a franchise. Interestingly, the coefficient on the dummy variable for presence in the area is positive, but it is not significant. This may be due to the very small presence allowed under FCC rules, or to the fact that different portions of the spectrum are used for very different purposes. The market debt to equity ratio has a negative coefficient in all four regressions, as expected, but is insignificantly different from zero. The coefficient on competitors' debt to equity ratio is negative, as expected, and significant at the 10% level.

Alternative Measures of Risk.

Two additional measures of bankruptcy risk are interest coverage and Z score. Interest coverage of each firm and the average interest coverage of the competing firms in each market are determined. A higher interest coverage implies a lower risk of bankruptcy. Thus, we would expect the coefficient on the interest coverage variable, and the competitors average interest coverage to be positive. Z score is a weighted average of several firm characteristics. A higher Z scores implies a lower risk of bankruptcy. Thus, we would expect the coefficient on Z score and the competition's average Z score to be positive.

The results of these regressions are in Table 3a. The coefficient on own debt equity ratio is negative and significant at the 5% level across all regressions. This result is consistent with the theory that as leverage increases, bids decrease. The competitors' debt equity ratio coefficient is also negative and significant across all regressions as the theory predicts. The Z score variable is insignificant. This suggests that while increases in debt lead to lower bids, adding Z score as a risk measure does not help predict bid levels. Own interest coverage is negative and significant in some models. This is in contrast to what we would expect since an increase in debt would lead to a decrease in interest coverage (all else equal). However, interest coverage may be a weaker signal than debt equity ratio about a firms actual probability of financial distress because operating income can very dramatically from period to period. If the firm experiences a period of low (or negative) operating income then interest coverage can fall to less then 1 or even become negative. However, if the firm has lots of cash on hand or a large amount of assets relative to debt, the firm may not be in danger of going bankrupt. This would be evident by a low debt-equity ratio. Thus, the fact that the own firm interest coverage coefficient is negative and significant does not necessarily mean that a firm closes to financial distress would increase their bid. On the contrary, we find that in the same regressions a firm with a higher debt-equity ratio will lower their bid. In addition, we find that the competitors interest coverage is insignificant but that coefficient on the competitor's debt equity ratio is negative and significant at the 5% level in all regressions. This suggests that as the competition increases their debt levels a firm will decrease their bid. This is consistent with the theory developed.

The size variable, the natural log of assets, is positive and significant at the 10% level in one of the models. The coefficients on per capita income and the adjacent dummy are again, positive and very significant. Table 3b) is very similar, except that we added a fixed effects dummy for Prime co. (more about this later). This dummy is significant, indicating that Prime indeed followed a different strategy, also, in this regression, assets and sales are more significant.

For another proxy of firm risk we looked at each firm's bond rating. We defined a dummy variable receiving the value of 1 if the bidder's bonds are rated AA or above. Again we calculated the average of the competitors bond ratings as well. A higher bond rating implies lower risk, and thus we would expect a higher bid. Thus, we expect the coefficient or the bond rating variable, and the competitors bond rating to be positive. The variable is insignificantly different from zero in all regressions (see Table 4).

Book Value Regressions

The next regressions (Table 6) uses book values instead of market values. The own debt to asset ratio has the right sign and it is significant for some models. Competitors' debt/equity ratios have the wrong sign but very low t values. We can expect a less significant result for the book ratios because clearly they are less representative of the actual state of affairs, especially in the bull market of the 90's. The coefficients of the other variables are similar with similar significance levels and similar interpretations as in the previous regression.

We have tried several other adjustments and different combinations of control variables. The negative sign for own debt and usually for competitors' debt prevailed. In addition, we estimated a fixed effects model to control for possible firm specific effects. Coefficients were generally not significant, except for Prime Co., which is included in the regressions above. Prime Co. entered the bidding with a very specific strategy. It is one of the few companies that had a national vision. According to Cramton (1997) Prime Co. is the only company that "reduced competition" (ibid. p. 454) because it had deep pockets. However, because of the composition of its partners, Prime Co. was only allowed to bid for 36% of the population in question. The lower competition in specific markets may account for the occasional significance of this firm specific dummy. When we include the other firm dummies the equations look qualitatively similar, however, no other firm dummy is significant.

These results are generally consistent with the hypothesis that as leverage increases the firm's bid decreases. In addition, there is evidence that as the leverage of the competition increases, the firm's bid decreases, as the theory predicts. We also identify two other factors that are significant in the FCC auction. First, income per capita is important to the value of a metropolitan area, and thus, has an important impact on the bid a firm submits for a region. Second, if a firm is winning an adjacent region this has a significant positive effect on the firm's bid for a specific area. This implies that there are synergies from owning rights in adjacent metropolitan regions. Surprisingly, prior presence does not seem to be a determining factor in bidding behavior, but this is perhaps because different wavelengths can be used for much different purposes, with no necessary synergies.

Probability of Winning

We next investigate if leverage is related to the probability of winning a market. An order probit analysis is used where the dependent variable is 1 if a firm wins the market and 0 otherwise. The natural log of assets, market debt equity ratio, and the adjacent dummy variable are used as independent variables. Natural log of assets controls for firm size, and the adjacent dummy controls for possible synergies in winning licenses in adjacent areas. If winning an adjacent market increases the value of a market to the firm (and thus the highest bid they are willing to submit) we would expect the adjacent market dummy to be positive. Debt to equity ratio along with a proxy for financial distress are used as independent variables to directly test the hypotheses that leverage affects the probability of winning. We run three regressions with different proxies for the probability of financial distress, interest coverage, zscore, and a bond rating dummy. We would expect a negative coefficient on the market debt-equity ratio if higher debt levels lead to a lower probability of winning. For the financial distress proxies, we expect a higher probability of distress to lead to a lower probability of winning. Higher interest coverage, lower zscore, and lower bond rating all imply a higher probability of financial distress. Thus we would expect a negative coefficient on interest coverage, and a positive coefficient on zscore and the bond rating dummy.

The results are reported in Table 7. The first column shows that Interest coverage is not significantly related to the probability of winning. In the next two columns the coefficient on zscore and on the bond rating dummy are both positive and significant. Thus two of the three proxies for financial distress show that firms with a higher probability of financial distress are less likely to win. The coefficient for market debt-equity ratio is negative and significant in one of the three regressions. It is insignificant in the other two regressions. Overall the evidence is consistent with the theory that more debt and a higher probability of financial distress result in a lower probability of winning.

3 Conclusion

This paper presents a theoretical model predicting how leverage should affect bidding behavior in private value auctions. It is shown that both the degree of leverage of the bidding firm and the debt-equity ratio of the competition are important factors in the bid a firm is willing to submit. In particular, as a firm increases its debt level, the highest bid it is willing to submit decreases. As the competition increases their debt level, this also causes the firm to decrease its bid.

We investigate an FCC auction to determine whether the effect of debt on bidding behavior is economically significant. We find that as a firm’s own debt level and as the competitions’ debt levels increase, firms tend to submit lower bids. This supports the theoretical model developed in this paper. We also find that income per capita and winning adjacent markets strongly affect the bids submitted by different companies.

Appendix A

The following public companies participated in the FCC auction for Block A and B:

Ameritech Wireless Communication
American Portable Telecommunication
AT&T Wireless PCS. Inc.
Bell South Personal Communication
Century Communication Corp.
Comcast Telephony Services
Continental Cablevision, Inc.
Cox Cable Communications, Inc.
GTE Macro Communications Corp.
Pacific Telesis Mobile Service
PhillieCo, L.P.
PrimeCo
Bell Atlantic
Southwestern Bell Mobile Systems
WirelessCo, L.P.

Appendix B: Description of FCC auction.[17]

In the mid-90's, the Federal Communications Commission adopted a new way of assigning licenses for personal communication services (PCS) namely, a simultaneous multiple round auction. The format and the rules were developed with the help of auction experts Paul Milgrom, Robert Wilson and Preston McAfee.

In order to test and refine the auction design, the FCC first auctioned ten Narrowband (50kHz) licenses, which are used to provide paging services. This auction took place in July of 1994. Next, 30 regional Narrowband licenses were sold. The former auction raised $617 million dollars and the latter, in November of 1994, raised $395 million dollars. However, in some sense, these two auctions were but a dress rehearsal for the auction analyzed in this paper, which was a Broadband auction, i.e. 30 MHz licenses, for personal communication. This auction (A and B blocks) took place between December 1994 and March 1995 and raised 7.7 billion dollars for the government. It was followed by another Broadband auction that theoretically raised 10.2 Billion dollars. However, that auction, C block, was open only too small enterprises (annual revenues below $125 million) and featured generous payment schedules. Prices offered were very high and many winning bidders defaulted on the bid payment. Whereas the Narrowband auctions included relatively small firms, the A-B Block Broadband auctions analyzed here elicited bids from some medium size firms as well as the largest communication firms in the world. Furthermore, several alliances were formed. The variety of firms and the fact that many of them were publicly traded, make this auction especially suitable for this study, which requires financial information at the firm level.

The designers of the A-B blocks auction faced several important questions, and in general opted for a design that was as transparent and accessible as possible, while preventing the formation of monopolies. First, they had to decide between a sealed bid and an open auction. Although sealed bids tend to discourage collusion, the advantage of revealing more information, favored the open bid multiple round design. For similar reasons, a simultaneous auction, i.e. where all licenses are auctioned at the same time, was preferred to a sequential design. Also, the FCC decided against package bids, i.e. when you submit one bid for several regions or areas.

Several specific rules and regulations constrained the bidders. First, the FCC required that no bidder ended up with too much power. For the Narrowband spectrum, a firm could not hold more than three licenses in any market. For Broadband auctions, the spectrum was limited, so that a firm could not hold more than 45MHz in each market. This effectively meant that an incumbent (holding a 25 MHz band) could not

[17] This appendix is largely based upon Cramton (1997).

compete in the A-B block auction, and also, that each bidder could obtain at most one license per market.

Payments were required in three stages. First, an up front payment, which assured eligibility. The payment was 2 cents for each MHz x Population. For example, for a million people and 30 MHz, one had to pay $600,000 up front. The winner was expected to provide a down payment of 20% five business days after the close of the auction, and the balance was paid 5 business days after the license had been formally awarded. Licenses were typically awarded one to three months after the auction.

Bidding was in discrete increments, initially set at the greater of 5% or 2 cents per MhzPop. There were three activity stages set by the FCC, as proposed by Paul Milgrom and Robert Wilson. In the initial stage each bidder had to be active (submit bids) for at least one third of his current eligibility (in terms of MHz pop). If activity fell below the one-third level, eligibility was reset to three times the actual level of bidding activity. For example, if a bidder was eligible to bid on 180 million MHz x pop , which would buy six 30 MHz licenses in areas with one million people each, then if valid bids for at least two such licenses were not placed, eligibility was reduced. If a bid for only one license was placed, eligibility was reduced to 90 million. In stage 2, the activity level was raised to 2/3 of the eligibility, and to 100% in the third stage. There were up to 5 waivers available per bidder. The FCC was also able to control the pace of bidding activity through the number of rounds per day. In the Narrowband auction there were several rounds per day, whereas in the Broadband auction initially only one round per day was conducted and then it was increased to two rounds as the auction progressed. Clearly all these rules and regulations had an impact on bidding behavior, however, proxies for differential effects on different bidders are difficult to conceptualize.

The auction ended if a single round passed with no bids in any market. Each bidder was fully informed about the identity, the eligibility, and the bids of all competitors. The Narrowband auctions ended after 47 and 105 rounds respectively. The auction discussed in this paper ended after 112 rounds. Bid withdrawal was possible, but it entailed a penalty. Bidders in the Broadband auctions formed alliances, even though these alliances decreased the number of markets in which each alliance could bid. The bidders in the Broadband auction were very cautious, bids were rarely increased by more than the minimum level. Most firms kept activity level near the minimum necessary to maintain eligibility. This contrasted sharply with the Narrow band experience. There were 21 bid withdrawals in the broadband auctions, mostly in round three, but only 6 qualified for a penalty. In the end, all licenses were sold and all monies paid, unlike the C block auction, which resulted in higher prices but many bankruptcies and protracted legal settlements well into 1998.

References:

Allen, Franklin, (1987) "Capital Structure and Imperfect Competition in Product Markets," Discussion paper, University of Pennsylvania.

Altman, Edward, Diane Cooke, and Vellore Kishore (1999) "Defaults & Returns on High Yield Bonds: Analysis Through 1998 & Default Outlook for 1999-2001," New York University Salomon Center Report.

Brander, J. and T.R. Lewis (1986) "Oligopoly and Financial Structure: the Limited Liability Effect," *American Economic Review*, December, pp.956-970.

Chevalier, Judith A., (1995a) "Do LBO Supermarkets Charge More? An Empirical Analysis of the Effects of LBOs on Supermarket Pricing," *Journal of Finance*; 50(4), September, pp. 1095-1112.

Chevalier, Judith A., (1995b) "Capital Structure and Product Market Competition: An Empirical Study of Supermarket LBO's," *American Economic Review*; 85,June, pp. 415-435.

Clayton, Matthew J., (1999) ''Debt, Investment, and Product Market Competition,'' New York University, Working Paper.

Chowdhry, B. and V. Nanda (1993) "The Strategic Role of Debt in Takeover Contests," *Journal of Finance*, 48: 731-745.

Cramton, Peter (1997) "The FCC Spectrum Auctions: an Early Assessment" *Journal of Economics and Management Strategy,* Fall, Vol. 6 # 3, pp. 331-495.

Daniel, Kent and David Hirshleifer, (1996) "A Theory of Costly Sequential Bidding," Kellogg Graduate School of Management, Working Paper.

Dammon, R. and L. Senbet, (1988) "The Effects of Taxes on the Interaction between Production and Finance," *Journal of Finance*, June, pp.357-374

Dasgupta, D., and S. Titman, (1998) "Pricing Strategy and Financial Policy," *Review of Financial Studies,* Winter, 11: 705-737.

DeAngelo, H. and R.W. Masulis, (1980) "Optimal Capital Structure Under Corporate and Personal Taxation," *Journal of Financial Economics*, March, pp.3-29

Dotan, A. and S. A. Ravid, (1985) "On the Interaction of Real and Financial Decisions of the Firm Under Uncertainty," *Journal of Finance*, June, pp.501-517.

Fishman M., (1988) “A Theory of Preemptive Takeover Bidding,” *Rand Journal of Economics*, 19: 88-101.

French, K. and R. McCormick, (1984) ‘‘Sealed Bids, Sunk Costs, and the Process of Competition,’’ *Journal of Business*, 57: 417-441.

Hite, G.L., (1978) “Leverage, Output Effects and the M-M Theorems,” *Journal of Financial Economics*, March, pp.177-202.

Holt, C., (1980) “Competitive Bidding for Contracts under Alternative Auction Procedures,” *Journal of Political Economy*, June, 88: 433-45.

Jensen, M., and H. Meckling, (1976) “Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure,” *Journal of Financial Economics*, October, pp. 305-360.

Maksimovic, V. (1988) “Capital Structure in Repeated Oligopolies,” *Rand Journal of Economics*, 19:3, pp.389-407.

Maksimovic, V. and M. Kim (1990) “Debt and Input Misallocation,” *Journal of Finance*, July, pp. 795-816.

Maskin, E., and J. Riley, (1984) “Optimal Auctions With Risk Averse Buyers,” *Econometrica*, November, pp. 1473-518.

Maskin, E., and J. Riley, (1985) “Auctions Theory with Private Values,” *American Economic Review*, May, pp. 150-5.

Maskin, E., and J. Riley, (1994) “Asymmetric Auctions,” October 1994, MIMEO.

McAfee, R. P., and J. McMillan (1996) “Analyzing the Airwave Auctions,” *Journal of Economic Perspectives* Vol. 10 No. 1 pp, 159 – 175.

McMillan, J., M. Rothschild, and R. Wilson, “Introduction,” *Journal of Economics and Management Strategy*, Fall 1997, Vol. 6 No. 3. pp. 425 –430.

Milgrom, P. (1989) “Auctions and Bidding: A Primer,” *Journal of Economic Perspectives*, Summer 3: 3-22.

Millgrom, P. and J. Roberts (1990) “Rationalizability, Learning, and Equilibrium in Games with Strategic Complementarities,” *Econometrica*, 58: 1255-1277.

Milgrom, P., and R. Weber, (1982) “A Theory of Auctions and Competitive Bidding,” *Econometrica*, September, pp. 1089-122.

Myers, S.C., (1977) “Determinants of Corporate Borrowing,” *Journal of Financial Economics*, November, pp.147-176.

Myerson R., (1981) “Optimal Auction Design,” *Mathematics of Operations Research*, 6: 58-73.

Phillips, G.M., (1995) “Increased Debt and Industry Product Markets-An Empirical Analysis,” *Journal of Financial Economics*, 37: pp. 189-238.

Porter, R., 1995, ‘‘The Role of Information in U.S. Offshore Oil and Gas Lease Auctions,’’ *Econometrica*, 63: 1-27.

Ravid, S.A., (1988) “On Interactions between Production and Financial Decisions,” *Financial Management*, Fall, pp.87-99.

Ravid, S. A., (1997) ‘‘Leverage Changes And Product Pricing Incentives-A Tax Induced Analysis,’’ Working Paper.

Rice, J., (1988) Mathematical Statistics and Data Analysis.

Riley, J., and W. Samuelson, (1981) “Optimal Auctions,” *American Economic Review*, June, pp. 381-92.

Robinson, M., (1985) “Collusion and the Choice of Auction,” *Rand Journal of Economics*. Spring, pp. 141-145.

Showalter, D., (1995) “Oligopoly and Financial Structure: Comment.” *American Economic Review,* 85: 647-653.

Smiley, A., (1979) ‘‘Competitive Bidding Under Uncertainty: The Case of Offshore Oil,’’ Cambridge: Ballinger Press.

Wilson, R., (1977) ‘‘A Bidding Model of Perfect Competition,’’ *Review of Economic Studies*, 44: 511-518.

Vickrey, W., (1961) “Counterspeculation, Auctions, and Competitive Sealed Tenders,” *Journal of Finance*, March, pp. 8-37.

Explanation of variables:

Per capita income of market: is the income per capita of the region being bid upon.

High bid per capita is the highest bid each firm submitted in each region per population of that region.

Adjacent dummy takes the value of 1 if the firm has won an adjacent region during this auction, and takes a value of
otherwise.

The current market dummy takes the value of 1 if the firm has a presence in the market (as defined by the FCC) and 0
otherwise.

Natural log of sales is the natural log of the bidding firm's sales over the 12 months prior to the auction.

Natural log of assets is the natural log of the bidding firm's assets as of December 31, 1994.

Book debt to asset ratio is the debt to asset ratio of the bidding firm in book values.

Competitors book debt to asset ratio is a weighted average of the competing firms' debt to asset ratio in book values. Market debt to equity ratio is the debt to equity ratio of the bidding firm in market values.

Competitors market D/E ratio is the average of the competing firms' debt to equity ratio in market values.

Interest coverage is the firm's interest coverage.

Competitors interest coverage is a weighted average of the competing firms' interest coverage.

Z-score is a five factor multiple discriminate analysis, using weights from Altman.

Bond AA or higher dummy takes the value 1 if the firm's bonds are rated AA or higher, and 0 otherwise.

(Above dummy) x (market D/E ratio) is the interaction term, which is Bond AA or higher dummy x market D/E ratio.

PrimeCo dummy takes the value of 1 if the bidding firm is PrimeCo and 0 otherwise.

Table 1: Descriptive statistics of variables.

Variable	Mean	S.D.	Maximum	Minimum
Per capita income of market	15.596	2.292	20.079	5.124
High bid per capita	12.584	7.599	31.902	0.600
Adjacent dummy	0.307	0.463	1.000	0.000
Current market dummy	0.073	0.262	1.000	0.000
Natural log of sales	9.104	1.472	11.227	6.032
Natural log of assets	9.778	1.120	11.281	7.536
Book debt to asset ratio	0.712	0.130	1.175	0.457
Competitors book D/E ratio	0.749	0.044	0.818	0.457
Market debt to equity ratio	0.787	0.412	3.111	0.102
Competitors market D/E ratio	0.833	0.247	2.001	0.102
Interest coverage	3.965	1.465	6.308	0.221
Competitors interest coverage	4.584	1.067	6.003	2.230
Z-score	3.816	2.884	8.796	0.305
Bond AA or higher dummy	0.320	0.468	1.000	0.000
Competitors Bond dummy	0.320	0.302	1.000	0.000
PrimeCo dummy	0.120	0.326	1.000	0,000

Table 2: Market Value Regressions

This table presents the results of OLS regressions where the dependent variable is the highest bid a firm submitted in a market. T-statistics appear in parentheses beneath each coefficient estimate.

Variable	Estimate	Estimate	Estimate	Estimate
Constant	2.337 (0.37)	2.432 (0.39)	2.131 (0.29)	2.234 (0.30)
Per Capita Income	0.858 (3.34)***	0.848 (3.28)***	0.858 (3.34)***	0.848 (3.28)***
Natural Log of Sale	0.039 (0.09)	0.034 (0.08)		
Natural Log of Assets			0.058 (0.10)	0.053 (0.09)
Market D/E ratio	-1.717 (-1.09)	-1.847 (-1.15)	-1.725 (-1.09)	-1.856 (-1.15)
Market D/E ratio of Competition	-4.404 (-1.78)*	-4.289 (-1.72)*	-4.406 (-1.79)*	-4.290 (-1.73)*
Adjacent Market Dummy	4.986 (3.77)***	5.064 (3.79)***	4.991 (3.80)***	5.069 (3.83)***
Current Market Dummy		1.273 (0.55)		1.273 (0.55)
R^2	0.1529	0.1547	0.1529	0.1547
Adjusted R^2	0.1235	0.1192	0.1235	0.1192

Significant at 1%(***), 5%(**), and 10%(*) levels.

Table 3a: Market Value Regressions

This table presents the results of OLS regressions where the dependent variable is the highest bid a firm submitted in a market. T-statistics appear in parentheses beneath each coefficient estimate.

Variable	Estimate	Estimate	Estimate	Estimate
Constant	-4.423	2.982	-4.220	2.963
	(-0.42)	(0.38)	(-0.40)	(0.37)
Per Capita Income	0.829	0.834	0.833	0.833
	(3.26)***	(3.28)***	(3.27)***	(3.26)***
Natural Log of Sale		1.624		1.639
		(1.71)*		(1.51)
Natural Log of Assets	2.361		2.244	
	(1.80)*		(1.65)	
Market D/E ratio	-5.160	-4.751	-5.183	-4.759
	(-2.29)**	(-2.21)**	(-2.29)**	(-2.19)**
Market D/E ratio of Competition	-5.732	-5.587	-5.633	-5.594
	(-2.22)**	(-2.16)**	(-2.16)**	(-2.14)**
Interest Coverage	-1.951	-1.781	-1.780	-1.802
	(-2.08)**	(-2.00)**	(-1.68)*	(-1.57)
Competitors Interest Coverage	-0.831	-0.878	-0.877	-0.874
	(-1.41)	(-1.49)	(-1.45)	(-1.44)
Z-score			0.105	-0.010
			(0.35)	(-0.03)
Adjacent Market Dummy	4.502	4.224	4.272	4.241
	(3.43)***	(3.14)***	(2.90)***	(2.88)***
R^2	0.1869	0.1851	0.1876	0.1851
Adjusted R^2	0.1468	0.1449	0.1415	0.1389

Significant at 1%(***), 5%(**), and 10%(*) levels.

Table 3b: Market Value Regressions

This table presents the results of OLS regressions where the dependent variable is the highest bid a firm submitted in a market. T-statistics appear in parentheses beneath each coefficient estimate.

Variable	Estimate	Estimate	Estimate	Estimate
Constant	-8.572	-0.018	-8.518	-0.361
	(-0.82)	(-0.00)	(-0.81)	(0.05)
Per Capita Income	0.905	0.910	0.906	0.905
	(3.59)***)	(3.61)***	(3.58)***	(3.57)***
Natural Log of Sale		1.852		2.064
		(1.97)*		(1.91)*
Natural Log of Assets	2.706		2.681	
	(2.08)**		(1.99)**	
Market D/E ratio	-5.482	-4.999	-5.485	-5.118
	(-2.47)**	(-2.36)**	(-2.46)**	(-2.39)**
Market D/E ratio of Competition	-4.961	-4.805	-4.944	-4.879
	(-1.94)*	(-1.87)*	(-1.92)*	(-1.89)*
Interest Coverage	-2.329	-2.124	-2.294	-2.425
	(-2.49)**	(-2.39)**	(-2.15)**	(-2.09)**
Competitors Interest Coverage	-0.791	-0.845	-0.801	-0.790
	(-1.37)	(-1.46)	(-1.34)	(-1.32)
Z-score			0.021	-0.133
			(0.07)	(-0.40)
Adjacent Market Dummy	4.450	4.134	4.405	4.369
	(3.45)***	(3.12)***	(3.04)***	(3.01)***
Prime Dummy	4.373	4.321	4.358	4.435
	(2.43)**	(2.40)**	(2.39)**	(2.43)**
R^2	0.2195	0.2170	0.2195	0.2179
Adjusted R^2	0.1752	0.1726	0.1694	0.1676

Significant at 1%(***), 5%(**), and 10%(*) levels.

Table 4: Market Value Regressions

This table presents the results of OLS regressions where the dependent variable is the highest bid a firm submitted in a market. T-statistics appear in parentheses beneath each coefficient estimate.

Variable	Estimate	Estimate	Estimate	Estimate
Constant	2.259 (0.29)	2.380 (0.26)	0.981 (0.12)	-6.659 (-0.60)
Per Capita Income	0.894 (3.38)***	0.894 (3.38)***	0.949 (3.59)***	0.942 (3.57)***
Natural Log of Sale	-0.042 (-0.06)		1.764 (1.71)*	
Natural Log of Assets		-0.051 (-0.06)		2.538 (1.89)*
Market D/E ratio	-1.610 (-0.862)	-1.613 (-0.88)	-4.768 (-2.11)**	-5.516 (-2.25)**
Market D/E ratio of Competition	-4.198 (-1.63)	-4.193 (-1.63)	-4.754 (-1.84)*	-4.874 (-1.89)*
Interest Coverage			-2.180 (-2.41)**	-2.468 (-2.54)**
Competitors Interest Coverage			-1.153 (-1.36)	-1.071 (-1.27)
Bond Rating Dummy 1 = AA or higher	-0.181 (-0.08)	-0.195 (-0.09)	0.603 (0.25)	1.198 (0.53)
Competitors Bond Rating	-1.180 (-0.57)	-1.181 (-0.57)	1.448 (0.49)	1.271 (0.44)
Adjacent Market Dummy	4.962 (3.75)***	4.956 (3.74)***	4.060 (3.02)***	4.295 (3.25)***
Prime Dummy	3.719 (1.55)	3.728 (1.59)	4.048 (1.71)*	3.726 (1.62)

R^2	0.1791	0.1791	0.2188	0.2223
Adjusted R^2	0.1325	0.1325	0.1626	0.1663

Significant at 1%(***), 5%(**), and 10%(*) levels.

Table 5: Interaction Regressions

This table presents the results of OLS regressions where the dependent variable is the highest bid a firm submitted in a market. T-statistics appear in parentheses beneath each coefficient estimate.

Variable	Estimate	Estimate	Estimate
Constant	6.606	5.483	2.860
	(0.71)	(0.69)	(0.35)
Per Capita Income	0.829	0.880	0.832
	(3.25)***	(3.46)***	(3.26)***
Natural Log of Sale	1.194	1.188	1.669
	(1.11)	(1.21)	(1.50)
Market D/E ratio	-6.163	-3.852	-4.747
	(-2.15)**	(-1.75)*	(-2.20)**
Market D/E ratio of Competition	-5.449	-5.146	-5.603
	(-2.09)**	(-2.33)**	(-2.15)**
Interest Coverage	-2.203	-2.102	-1.841
	(-2.09)**	(-2.33)**	(-1.55)
Competitors Interest Coverage	-0.866	-0.876	-0.868
	(-1.47)	(-1.50)	(-1.43)
Adjacent Market Dummy	4.296	3.985	4.269
	(3.18)***	(2.96)***	(2.90)***
(Market D/E)*Interest Coverage	0.974		
	(0.75)		
(Market D/E)*Bond Rating Dummy		4.318	
		(1.73)*	
(Market D/E)*Z Score			-0.023
			(-0.08)
R^2	0.1883	0.2021	0.1851
Adjusted R^2	0.1423	0.1568	0.1389

Significant at 1%(***), 5%(**), and 10%(*) levels.

Table 6: Book Value Regressions

This table presents the results of OLS regressions where the dependent variable is the highest bid a firm submitted in a market. T-statistics appear in parentheses beneath each coefficient estimate.

Variable	Estimate	Estimate	Estimate	Estimate
Constant	-10.248	-10.534	-14.963	-20.317
	(-0.85)	(-0.84)	(-1.22)	(-1.50)
Per Capita Income	0.920	0.921	0.882	0.890
	(3.53)***	(3.53)***	(3.44)***	(3.46)***
Natural Log of Sale	0.277		2.668	
	(0.54)		(2.52)**	
Natural Log of Assets		0.289		2.909
		(0.44)		(2.19)**
Book Debt to Asset ratio	-5.133	-4.731	-17.676	-14.883
	(-0.87)	(-0.82)	(-2.33)**	(-2.04)**
Book Debt to Asset ratio of Competition	10.135	9.702	14.986	11.497
	(0.73)	(0.70)	(1.09)	(0.84)
Interest Coverage			-2.217	-1.931
			(-2.62)***	(-2.32)**
Competitors Interest Coverage			-0.496	-0.401
			(-0.90)	(0.73)
Adjacent Market Dummy	5.037	5.077	4.308	4.755
	(3.81)***	(3.84)***	(3.24)***	(3.60)***
Prime Dummy	4.014	4.032	5.119	5.050
	(2.20)**	(2.21)**	(2.78)***	(2.72)***
R^2	0.1695	0.1690	0.2101	0.2017
Adjusted R^2	0.1347	0.1341	0.1653	0.1564

Significant at 1%(***), 5%(**), and 10%(*) levels.

Table 7: Determinates of Probability of Winning

This table presents the results of ordered probit regressions where the dependent variable is one if the firm wins a market it bid upon and zero otherwise. T-statistics appear in parentheses beneath each coefficient estimate.

Variable	Estimate	Estimate	Estimate
Natural Log of Assets	0.353	0.657	-0.058
	(-0.28)	(3.77)***	(-0.42)
Market D/E ratio	-0.283	-1.866	0.313
	(-0.616)	(-2.98)***	(1.04)
Interest Coverage	-0.149		
	(-0.84)		
Z Score		0.320	
		(4.56)***	
Rate 3			0.737
			(2.35)**
Adjacent Market Dummy	0.835	0.339	0.789
	(3.39)***	(1.22)	(3.19)***

Significant at 1%(***), 5%(**), and 10%(*) levels.