SYNERGIES IN RECURRING PROCUREMENT AUCTIONS: AN EMPIRICAL INVESTIGATION

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This article examines the impact of synergies on bidder behavior in recurring road construction procurement auctions. The study reveals that projects are spatially correlated. When bidders with potential synergies participate, the results indicate that their probability of bidding and winning increases and they bid more aggressively. Finally, the study shows that a firm that is capacity unconstrained will bid more aggressively than one that is capacity constrained. (*JEL* D44)

I. INTRODUCTION

This study empirically investigates the impact of potential synergies and competitive advantages on bidder behavior in recurring auctions of road construction contracts held by the Oklahoma Department of Transportation (ODOT) from January 1997 to August 2000. In this study, synergies are defined as complementarities associated with winning an additional project(s) in a particular geographic area. Furthermore, a firm's valuation of a project may depend on competitive advantages associated with its familiarity with local market resources and with inherent firm efficiencies. The first two advantages are crucially correlated to geographical space.

When projects are irregularly dispersed and recorded as points in the landscape, it is more difficult to define a set of "influential" neighboring projects. Therefore, spatial relationships that reflect a decaying distance between points or locations identified by latitudes and longitudes are often assumed to be appropriate. Moreover, firms bidding for different projects in different regions face different weather conditions and labor, transportation, and material costs. When empirical studies cannot control for such variables, paying attention to spatial dependence allow researchers to capture these information in the residuals. Thus, when there is a correlation among projects due to location (spatial correlation), ignoring the spatial interdependence of projects is like ignoring the sequential ordering in time-series studies.

Each year, federal and state agencies initiate numerous auctions of contracts that are spatially correlated.[1] An understanding of these spatial correlations could help state and federal governments sequence auctions of related projects more efficiently. This understanding is also beneficial to bidding firms, enabling them to take advantage of the synergies and economic advantages.

Only recently have equilibrium models appeared in the literature on recurring auctions. Two concerns in recurring auctions are bidders' extraction of synergies between goods and the enhancement of efficiency in distribution of goods (McMillan 1994, Cramton 1997). Motivated by these concerns, Krishna and Rosenthal (1996) and Branco (1997) show that in recurring auctions, bundle bidders who bid on multiple objects bid more aggressively than unit bidders who bid on a single object. Jeitschko and Wolfstetter (2002) have described bidding behavior in first-price

1. For example, cable television and telecommunications licenses, timber auctions, and road-construction auctions. See Rusco and Walls (1999).

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ABBREVIATIONS

ODOT: Oklahoma Department of Transportation
OLS: Ordinary Least Squares
LM: Lagrange Multiplier

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sealed-bid ascending recurring auctions and show that bidders who have previously won may experience the potential synergies in subsequent auctions.

Empirical research on synergies in auctions is scarce. Gandal (1997) shows that complementarities associated with winning multiple projects in a particular geographic area enhanced the values of neighboring CATV licenses in major metropolitan areas in Israel. Ausubel et al. (1997) show that there are geographic synergies associated with winning multiple adjacent licenses in spectrum license auctions in the United States.[2] Rusco and Walls (1999) show that in repeated spatially correlated timber auctions, bidders with complementarities associated with winning multiple projects bid more aggressively. Jofre-Bonet and Pesendorfer (2000a,b) use data from repeated highway construction procurement auctions to show that the distance between firms and projects have a negative impact on the submission and value of bids. In addition, they have shown that capacity unconstrained bidders (bidders with low backlogs) are more likely to submit a bid and to bid more aggressively than are bidders with high capacity constraints. Porter and Zona (1999), in their study of dairies bidding for contracts to supply milk, and Bajari (2001), in his study of highway construction firms bidding for procurement contracts, have also shown that location plays a major role in a firm's bidding behavior when collusion between firms is present.

In this study, I examine bidders' behavior in recurring auctions of road construction contracts held by ODOT between January 1997 and August 2000 to determine whether they have been affected by the potential synergies and competitive advantages (or no advantages). This study documents the participation patterns and differences in bidding patterns among firms to argue that they are caused by anticipated synergies that are spatially correlated and reports that, when a firm with potential synergies and competitive advantages participates in a recurring procurement auction, its probability of winning the auction, conditional on bidding, increases.[3] Furthermore, this study finds that firms with potential synergies and competitive advantages bid more aggressively. These empirical findings support the theoretical findings of Jeitschko and Wolfstetter (2002). Finally, the study supports Jofre-Bonet and Pesendorfer's (2000a,b) and De Silva et al.'s (2002) claim that when a firm's capacity constraint is low, it tends to bid more aggressively.

Section II describes the modeling framework used in this study. Section III describes the data set; section IV reports the results of the empirical analysis; and section V summarizes the main findings of the study.

II. MODEL

Jeitschko and Wolfstetter (2002) developed the comparative model used herein. They analyzed economic advantages in terms of economies of scale in first-price sealed-bid ascending auctions. This study adapts their model to investigate first-price sealed-bid auctions of construction contracts and emphasizes synergies in which the lowest bidder is awarded the project.

Consider a sequence of two auctions in each of which a single project is auctioned to two bidders.[4] The winner of the first auction is hereafter referred to as the *incumbent* and the loser is the *contestant*. Prior to the first auction, each bidder privately observes his cost for the first project (C) but not the cost for the second project (C_H). A winner (the bidder with the lowest bid) is announced at the conclusion of the first auction, and then the bidders privately observe C_H, a random variable that depends on the history (H) of a firm winning or losing the first auction. The incumbent bidder has the potential to gain from synergies by winning the second project. In the second auction, the cost of the incumbent bidder is C_I and that of the contestant bidder is C_C. C is drawn from a known support normalized to $\{0, c\}, c > 0$, with probability ρ, where $0 < \rho := \Pr\ \{C = c\} < 1$. The cost of the second project is also drawn from $\{0, c\}$, $c > 0$, but C_H and C_C are stochastically independent. The probability of the event $C_H = c$, $(H \in \{I, C\})$ is not the same for incumbent and contestant bidders. Whereas the incumbent bidder with potential synergies gains from winning multiple projects in the

2. This study investigates the existence of synergies in broadband personal communication service spectrum ascending-bid auctions in United States.

3. Bidders who stand to experience low cost with a greater probability in the future.

4. The study differentiates between groups of two bidders with emphasis on *incumbent* bidders and *contestant* bidders.

same geographic location, the contestant bidder may not. The incumbent bidder has a higher probability (σ) of drawing a lower cost for the project as compared to the contestant (i.e., $0 < \sigma < \rho < 1$) due to potential synergies and competitive advantages, but if they do not observe competitive advantages, their probability of incurring a lower cost is $0 < \rho < \sigma < 1$. Hence, anticipated synergies and competitive advantages increase the expected value of a project for an incumbent.

Note that risk-neutral bidders maximize the sum of the payoffs from both auctions by placing real-valued bids. Thus the study assumes that bidders do not discount their expected payoffs for the second auction. A compelling argument for no discounting is that ODOT projects are auctioned off in relatively short time intervals compared to the overall work schedule of the participating firms. Furthermore, the bidders do not know about upcoming projects until the winners are notified about the results of the current auction. This supports another assumption of the theoretical model, which states that the costs for the second auction are only drawn after the winner of the first auction is announced. Therefore, the assumption of no discounting is innocuous as far as the predictions for the data in question are concerned.

Jeitschko and Wolfstetter (2002) suggest that in the first auction, bidders with high costs will bid c and bidders with low costs will submit a bid drawn from a distribution that lies below c. Thus, the low-cost bidder will win the project because the analysis is for first-price sealed-bid construction contracts. In subsequent auctions, incumbents with potential synergies or with economic advantages bid more aggressively than contestants. From their analysis one can establish that the cost distribution of a contestant stochastically dominates the distribution of an incumbent.

This study applies the model as follows: In a repeated procurement auction, the winner of a project will be viewed as an incumbent. When incumbents bid in related projects, they may observe potential synergies and therefore may bid more aggressively than contestants. However, incumbency is not permanent. A firm may lose its incumbency if it no longer has any ongoing projects and will then bid as a contestant. This study investigates the effects of potential synergies on the bidding behavior of incumbents and contestants. The next section constructs synergy and competitive advantage variables to investigate Jeitschko and Wolfstetter's (2002) theory and then presents the empirical results supporting their claims.

III. DATA

The data used in this analysis are made up of information on all road construction projects auctioned by ODOT from January 1997 to August 2000.[5] Projects are auctioned off once each month in a first-price sealed-bid format. The auctions include major projects like road construction and paving, traffic signaling, bridge construction and maintenance, as well as minor projects like drainage and clearance.[6] The state reserves the right to reject any bid that is 7% above the state's engineering cost estimate for the project, but there have been some exceptions to this rule mostly due to the underestimation of costs by the state. Generally, bidders must be prequalified to participate in these auctions. Prequalification involves bidders' submission of certified financial statements to ODOT and is related to the level of working capital available to the potential bidder as well as its history of successful completion of projects. The resultant evaluation is used to determine the size of projects a firm can bid on. Firms can be disqualified at any time if they fail to complete contracts successfully. Finally, bidders must make a down payment of 5% of the project's value when submitting a bid.[7]

The data examined in this study include descriptions of plan-holders (firms that purchase project plans), all bids for the project, and the winning bid (if the contract is awarded). The state also provides the location of each project, a description (e.g., bridge construction, asphalt paving, etc.), relevant details (e.g., the length and depth of the paving

5. Because I investigate synergies derived from divisional effects, statewide projects are excluded (three auctions).

6. Highway construction auctions have been examined in a number of papers, including Thiel (1988), Porter and Zona (1993), Jofre-Bonet and Pesendorfer (2000a,b) and Bajari (2000). But they do not investigate the bidder behavior due to synergies.

7. In general, these requirements establish some barriers for firms to extract synergies. Firms may have an ongoing project in an area but due to prequalification requirements may not be able to bid on upcoming projects even though they can realize synergies from it.

TABLE 1
Summary Statistics of Oklahoma Road Construction Auctions

Variable	Auction Statistics
Number of auctions	1734
Number of auctions w/winners	1409
Number of firms	284
Number of plans purchased	9526
Number of bids	5221
Average number of plan-holders per auction	5.5305 (3.0578)
Average number of bidders per auction	3.3026 (1.6843)
Number of incumbent plan-holders in their own division	1893
Number of incumbent plan-holders in different divisions	4516
Number of contestant plan-holders in their own division	939
Number of contestant plan-holders in different divisions	2178
Number of bids by incumbents who are bidding in their own division	1165
Number of bids by incumbents who are bidding in different divisions	2621
Number of bids by contestants who are bidding in their own division	492
Number of bids by contestants who are bidding in different divisions	943
Number of incumbent winners in their own division	399
Number of incumbent winners in different divisions	658
Number of contestant winners in their own division	135
Number of contestant winners in different divisions	217

Note: SDs in parentheses.

surface, the type of material to be utilized, the amount of excavation, etc.), duration (calendar days), and the total engineering estimate. Table 1 provides summary statistics on the number of auctions, the average number of plan-holders per auction, and the average number of bidders per auction. During the period under study, there were 1734 auctions, with an average of 5.5 plan-holders and 3.3 bidders per auction. Contracts were awarded in 1409 of the 1734 auctions. A total of 284 different firms held project plans, 213 bid on projects, and 144 won contracts.[8]

As shown in Figure 1, ODOT divides Oklahoma into eight divisions.[9] Most of the projects under study were located in Division 4 (278).[10] Most firms (49 out of 284) were also located in Division 4 and bid 2286 times, winning 612 projects. Table 2 shows the bid frequency by firm division and by project division. Out-of-state firms (identified by division = 0) bid all across Oklahoma. Their bid frequency on projects ranges from 6.8% (38 bids) in Division 2 to 20.7% (112 bids) in Division 8. Furthermore, they account for 15.34% of all projects in Division 1. Table 2 reveals that firms in Oklahoma have strong regional preferences, with firms located in a certain division tending to bid on projects in their own division. For example, 32.49% of all the bids submitted by firms in Division 1 were submitted to projects in that division. Furthermore, compared with other firm divisions, 28.29% of projects in Division 1 were submitted by firms in that division. This pattern can be observed for all project types.

8. There are several firms in the data sets that purchase plans, bid, and win frequently. The maximum number of bids we observe by one firm is 218 and the maximum number of wins by a firm is 59.

9. There are 77 counties in Oklahoma, and ODOT has divided them into eight divisions.

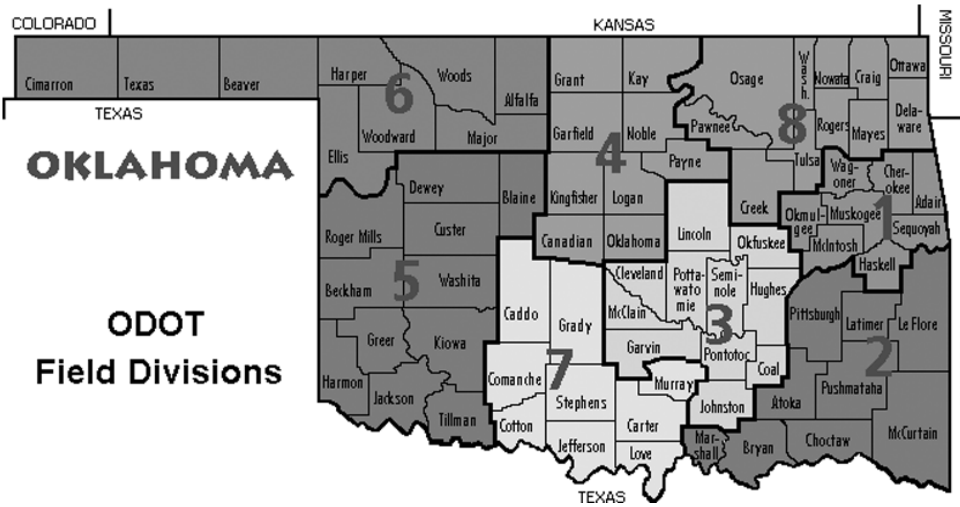
10. It is worthwhile to mention that Oklahoma City, the largest city in state of Oklahoma, is located in this division.

IV. EMPIRICAL ANALYSIS

The theoretical insights of Jeitschko and Wolfstetter (2002) specifically suggest the following results.

1. Incumbent bidders are more likely to bid in an auction. Furthermore, incumbents are more likely to submit lower bids and, consequently, win more.

FIGURE 1
ODOT Field Divisions



Source: Oklahoma Department of Transportation.

2. Contestants are less likely to bid in an auction compared to incumbents, submit less aggressive bids, and win with lower probability.

3. Efficient firms, that is, those who have experienced synergies, are more likely to bid in an auction compared to inefficient firms.

In addition to the above-mentioned theoretical predictions, studies by Jofre-Bonet and Pesendorfer (2000a, 2000b) and De Silva et al. (2002) have shown that capacity constrained bidders bid less aggressively.

I model the differences in bidding due to potential synergies in spatially correlated procurement auctions and use a simple reduced-form model of bidding. Three dependent variables that summarize the participation and bidding patterns in these auctions are examined: (1) bid dummy, (2) win, and (3) log of bids. To examine probability of participation, a dummy called *biddummy* was created. To examine the probability of winning conditional on bidding, a dummy, *win*, was constructed. To examine the variations of bids due to firm and auction characteristics, the log value of the bids is used as the dependent variable.

The independent variables that control for project characteristics are (1) a set of dummy variables for project types (P_j's), (2) the state's estimate of the engineering cost (log(*engest*)), and (3) the number of bidders (log(*#bidders*)). The project types include a set of six dummy variables: asphalt, clearance and bank protection, bridge work, grading and draining, concrete work, and signals and lighting. The omitted group is miscellaneous work, such as intersection modification, parking lot construction, and landscaping. The engineering cost estimates are constructed by the state by pricing each feature outlined in the design and then deriving an overall cost estimate for the project. Although the engineering cost estimate should control for project-specific differences in cost, certain project classes have different prequalification standards. Hence, the pool of potential bidders may differ somewhat across project types. With respect to information on the level of competitiveness in an auction, the study includes a variable to measure competition. As is standard in the auction literature, this study also controls for the number of bidders (log(*#bidders*)).

With respect to bidders' own characteristics, four measures are included in the regressions. The study categorizes incumbents and contestants into four different groups identified by three dummy variables: (1) incumbent bidders bidding in their own division (*dincumbent*),[11]

11. In this case the firm's location and project location are in the same division. For example a firm in Division 4 that has won a project in Division 4 and is bidding in Division 4 in subsequent auctions.

TABLE 2
Bid Frequencies by Firm Division and Project Division

Frequency Percent Row % Col. %	Projdiv-1	Projdiv-2	Projdiv-3	Projdiv-4	Projdiv-5	Projdiv-6	Projdiv-7	Projdiv-8	*Total*
Firmdiv-0	77 1.47 13.80 15.34	38 0.73 6.81 9.18	69 1.32 12.37 7.36	105 2.01 18.82 9.84	40 0.77 7.17 7.49	74 1.42 13.26 21.20	43 0.82 7.71 6.78	112 2.15 20.07 14.29	*558* *10.69*
Firmdiv-1	142 2.72 32.49 28.29	69 1.32 15.79 16.67	69 1.32 15.79 7.36	42 0.80 9.61 3.94	9 0.17 2.06 1.69	7 0.13 1.60 2.01	14 0.27 3.20 2.21	85 1.63 19.45 10.84	*437* *8.37*
Firmdiv-2	26 0.50 13.27 5.18	89 1.70 45.41 21.50	51 0.98 26.02 5.44	4 0.08 2.04 0.37	0 0.00 0.00 0.00	0 0.00 0.00 0.00	22 0.42 11.22 3.47	4 0.08 2.04 0.51	*196* *3.75*
Firmdiv-3	7 0.13 2.67 1.39	1 0.02 0.38 0.24	81 1.55 30.92 8.64	26 0.50 9.92 2.44	63 1.21 24.05 11.80	44 0.84 16.79 12.61	39 0.75 14.89 6.15	1 0.02 0.38 0.13	*262* *5.02*
Firmdiv-4	124 2.38 5.42 24.70	140 2.68 6.12 33.82	487 9.33 21.30 51.97	704 13.48 30.80 65.98	228 4.37 9.97 42.70	113 2.16 4.94 32.38	285 5.46 12.47 44.95	205 3.93 8.97 26.15	*2286* *43.78*
Firmdiv-5	3 0.06 1.16 0.60	2 0.04 0.77 0.48	25 0.48 9.65 2.67	30 0.57 11.58 2.81	101 1.93 39.00 18.91	56 1.07 21.62 16.05	35 0.67 13.51 5.52	7 0.13 2.70 0.89	*259* *4.96*
Firmdiv-6	0 0.00 0.00 0.00	1 0.02 3.13 0.24	0 0.00 0.00 0.00	0 0.00 0.00 0.00	3 0.06 9.38 0.56	28 0.54 87.50 8.02	0 0.00 0.00 0.00	0 0.00 0.00 0.00	*32* *0.61*
Firmdiv-7	9 0.17 2.60 1.79	19 0.36 5.49 5.49	53 1.02 15.32 5.66	35 0.67 10.12 3.28	65 1.24 18.79 12.17	13 0.25 3.76 3.72	147 2.82 42.49 23.19	5 0.10 1.45 0.64	*346* *6.63*
Firmdiv-8	114 2.18 13.49 22.71	55 1.05 6.51 13.29	102 1.95 12.07 10.89	121 2.32 14.32 11.34	25 0.48 2.96 4.68	14 0.27 1.66 4.01	49 0.94 5.80 7.73	365 6.99 43.20 46.56	*845* *16.18*
Total	*502* *9.62*	*414* *7.93*	*937* *17.95*	*1067* *20.44*	*534* *10.23*	*349* *6.68*	*634* *12.14*	*784* *15.02*	*5221* *100.00*

(2) incumbent bidders bidding in different divisions (*ndincumbent*),[12] (3) contestant bidders bidding in their own division (*dcontestant*), and (4) the omitted group—contestant bidders bidding in different divisions (*ndcontestant*). In the period under study, incumbent bidders bidding in their own division make up about 19.87% of plan-holders and 22.31% of bidders.

12. The different divisions are identified as divisions other than their own division where they have an ongoing project. For example a firm in Division 4 that has won a project in Division 2 and is bidding in Division 2 in subsequent auctions.

TABLE 3
Summary Statistics of Regression Variables

Variable	Mean (SD)
Log of Bids	12.8824 (1.5899)
Log of winning bids	12.6465 (1.5981)
Log of engineer's estimate	13.0738 (1.6957)
Log of number of bidders in an auction	1.2400 (0.473)
Probability of facing an incumbent who is bidding in his own division	0.2231 (0.4164)
Probability of facing an incumbent who is bidding in a different division	0.5020 (0.5000)
Probability of facing a contestant who is bidding in his own division	0.0942 (0.2922)
Probability of facing a contestant who is bidding in a different division	0.1806 (0.3847)
Log of firm's backlog	9.7314 (6.6558)
Firm's winning to bidding ratio	0.2317 (0.1724)

Out of the 9526 plans purchased in that period, incumbent bidders bidding in their own division purchased 1893 plans and, eventually, submitted 1165 bids. Out of the 1734 auctions under study, 778 contain incumbents bidding in their own division who won 399 projects (Table 1).[13]

Next, the study includes a variable that accounts for past success in auctions (*wbratio*). This variable is constructed as the ratio of the past number of wins to the past number of bids. It provides information on the previous success of a firm and is included to control for differences in firm efficiencies. In addition to the synergy variables, a backlog variable is constructed. For each firm, the average monthly value of every contract won is calculated. Each subsequent month, the average monthly value is subtracted from the remaining portion of the contract until the completion of the project. Thus, the total remaining value of the projects that a firm has undertaken can be calculated at any given point in time. The log of backlog variable is used to control for firms' capacity constraints.[14] See Table 3 for summary statistics.

Based on Jeitschko and Wolfstetter's (2002) theoretical predictions and Jofre-Bonet and Pesendorfer's (2000a, 2000b) and De Silva et al.'s (2002) findings, the following empirical results are expected in this study.

1. Incumbents bidding in their own region will have a higher probability to bid. They will also have a higher probability to win conditional on bidding, and will bid more aggressively compared to any other bidder because they would gain from potential synergies and competitive advantages associated with their familiarity with local market resources.
2. Contestants will have a low probability to bid and to win conditional on bidding and will bid less aggressively regardless of whether they bid in their own division or not.
3. Efficient firms will have a higher probability to bid and win and will bid aggressively.
4. Firms with low capacity constraints (high backlog) will bid less aggressively.

Bidding behaviors are analyzed using probits, ordinary least squares (OLS), and standard panel data techniques.[15] Thus, the basic structure of the empirical model is as follows:

$$\begin{aligned} y_i = \beta_0 + \sum_{j=1}^{6} \beta_j P_{ji} + \beta_7 \log(engest_i) \\ + \beta_8 \log(\#bidders_i) + \beta_9(dincumbent_i) \\ + \beta_{10}(ndincumbent_i) + \beta_{12}(dcontestant_i) \\ + \beta_{13}\log(backlog_i) + \beta_{14}(wbratio_i) + \varepsilon_{i\mu w}. \end{aligned}$$

As discussed earlier, interdependencies among projects and geographic areas may lead to spatial correlation among bids. If one observes spatial heterogeneity in a model, the estimation of that model with simple probits, OLS, and fixed effects will result in inefficient estimators. Therefore, this study will use spatial econometric techniques to analyze bidding behavior.[16] There has been very little research

13. Incumbents bidding in different divisions were present in 208 auctions, contestants bidding in their own division were present in 459 auctions, and contestants bidding in different actions were present in 1610 auctions.

14. The log of backlog is calculated as follows: $lbacklog = \log(backlog + 1)$.

15. The study will use fixed effects model to analyze the within firm bidding behavior.

16. Methods proposed to estimate spatial models and applied studies are spatial probit error models (McMillen 1992), LeSage (2000), and LeSage and Smith (2000); generalized estimations of the probit (Pinske and Slade 1998); generalized method of moments by LeSage (1999a,b), Kelejian and Prucha 1998, 1999), and Bell and Bockstael (2000), and simulated recursive sampling (Vijverberg 1997). For reviews see Anselin and Florax (1995).

on spatial models in auction markets,[17] and this research affords new insights into procurement auction markets with spatial properties. This study uses the Gibbs sampling Bayesian heteroscedastic spatial probit method and the Gibbs sampling Bayesian heteroscedastic spatial regression method introduced by LeSage (1999a,b).

There are numerous advantages to using the Gibbs sampling Bayesian heteroscedastic spatial regression and probit methods (LeSage 1999a). First, this method, unlike others, allows for the assumption of nonconstant variance for each region, resulting in efficient estimators. This can be easily explained by analyzing the structure of the error term. The random error vector, u, takes the following form: $u = \lambda Wu + \varepsilon$, where λ is a scalar parameter that indicates the magnitude of spatial correlation among projects and W is a known $n \times n$ spatial weight matrix generally constructed using latitude and longitude coordinates, as in this study. The random error vector, ε, is an $n \times 1$ vector with a nonconstant variance taking on different values for specific regions. Other methods, however, assume that there is a constant variance for all regions, meaning that there is no heterogeneity due to regions.

Second, unlike other methods, the Gibbs sampling approach constructs complete conditional distributions for all the parameters in the model that converge in the limit to their true distributions of the parameters. This technique allows for constructing efficient estimators.

The third advantage is that in the Gibbs sampling Bayesian heteroscedastic spatial probit methods, unlike other methods, one does not have to specify a functional form for the random error term, ε. This would be impractical for large models when specifying the functional form and the variables involved in the models for variance of the error term. The basic idea of the Gibbs sampling method is to create a large random sample of observations for the posterior density of parameters to be estimated and then approximate the shape of these probability densities.[18]

TABLE 4
Spatial Dependence Test Statistics

Model	Test Statistics
Spatial error model	
LM value	7.2370
Probability	0.0071
Mixed autoregressive model	
LM value	0.0148
Probability	0.9032

The Lagrange multiplier (LM) error test is used to test for spatial correlation. The null hypothesis of the LM test is that there is no spatial correlation in the models. The application of the LM test to the data set demonstrates that the model fits a spatial error model, in which the error terms exhibit spatial dependence.[19] The observed LM values and corresponding probabilities are given in Table 4. This further justifies the existence of spatial correlations in this auction market. In this case, this study uses the Gibbs sampling Bayesian heteroscedastic spatial error model to analyze the data.[20]

Next, the study estimates probit models for bid submission. The first column in Table 5 reveals that incumbent bidders bidding in their own division are most likely to submit a bid. Furthermore, incumbents bidding in different divisions and contestants bidding in their own division are also more likely to submit a bid compared to contestants bidding in different divisions. These results support Jeitschko and Wolfstetter's (2002) first two theoretical predictions. Firm efficiencies are captured by the past wins-to-bid ratio and this shows that efficient firms are more likely to submit bids. This result supports Jeitschko and Wolfstetter's (2002) third theoretical

17. Ausubel et al. (1997) show that there are geographic synergies associated with winning multiple PCS licenses. Rusco and Walls (1999) have shown spatial correlation in timber market auctions. Furthermore, Porter and Zona (1999), in their study of bidding by dairies for contracts to supply milk, and Bajari (2001), in his study of bidding by highway construction firms for procurement contracts, have also shown that location plays a major role in firm's bidding behavior.

18. Kernel density functions can be used to approximate these distributions.

19. There are three basic spatial models: (1) *general spatial model*, which includes both the spatial lagged term as well as a spatially correlated error structure; (2) *mixed autoregressive-regressive model*, in which the standard regression model is combined with a spatially lagged dependent variable; and (3) *spatial error model*. LeSage (1999a) defines these spatial models in detail in *Spatial Econometrics*.

20. See LeSage (1999a,b) for a brief description of the Gibbs sampling Bayesian heteroscedastic spatial regression/probit models.

TABLE 5
Probit Results for Probability of Bidding

Variable	Unadjusted for Spatial Correlation	Adjusted for Spatial Correlation
Constant	1.1705* (0.1686)	1.3067* (0.1877)
Project-1	0.1015 (0.0693)	0.1137 (0.0736)
Project-2	−0.0750 (0.0994)	−0.0583 (0.1106)
Project-3	−0.0244 (0.0669)	0.0196 (0.0697)
Project-4	−0.2138* (0.0749)	−0.2316* (0.0777)
Project-5	−0.0018 (0.1542)	0.0127 (0.1671)
Project-6	0.4524* (0.0923)	0.4983* (0.1035)
Log of engineer's estimate	−0.1013* (0.0121)	−0.1134* (0.0133)
Log of firm's backlog	−0.0082 (0.0053)	−0.0082 (0.0060)
Firm's winning to bidding ratio	0.3630* (0.0888)	0.4274* (0.0964)
An incumbent who is bidding in his own division	0.5736* (0.0833)	0.6200* (0.0946)
An incumbent who is bidding in a different division	0.5197* (0.0807)	0.5623* (0.0895)
A contestant who is bidding in his own division	0.2090* (0.0516)	0.2341* (0.0550)
λ		0.2864* (0.1412)
Number of observations	8954	8954
LR χ^2	654.65	

Note: SDs in parentheses.
*Denotes 95% statistical significance.

TABLE 6
Probit Results for Probability of Winning

Variable	Unadjusted for Spatial Correlation	Adjusted for Spatial Correlation
Constant	– 0.5384* (0.2342)	– 0.5883* (0.2590)
Project-1	0.2158* (0.0926)	0.2445* (0.1026)
Project-2	– 0.1847 (0.1380)	– 0.2406 (0.1651)
Project-3	0.0054 (0.0904)	0.0040 (0.1008)
Project-4	0.0613 (0.1064)	0.0660 (0.1197)
Project-5	– 0.0715 (0.2123)	– 0.1168 (0.2682)
Project-6	0.0218 (0.1105)	0.0187 (0.1183)
Log of engineer's estimate	– 0.0292 (0.0171)	– 0.0340* (0.0197)
Log of firm's backlog	– 0.0344* (0.0064)	– 0.0378* (0.0075)
Firm's winning to bidding ratio	0.7547* (0.1216)	0.8482* (0.1409)
An incumbent who is bidding in his own division	0.6636* (0.1030)	0.7392* (0.1166)
An incumbent who is bidding in a different division	0.4300* (0.0995)	0.4782* (0.1128)
A contestant who is bidding in his own division	0.0931 (0.0766)	0.1083 (0.0875)
λ		0.2264 (0.1325)
Number of observations	5221	5221
LR χ^2	148.68	

Note: SDs in parentheses.
*Denotes 95% statistical significance.

finding. Column 2 of Table 5 shows the Gibbs sampling Bayesian heteroscedastic spatial probit results. The spatial probit results are also significant and consistent with the hypothesis. Another important point is that the λ parameter is significant. This indicates that projects are geographically correlated, and as the distance increases, the spatial correlation decreases. Both models show that bidders with potential synergies are more likely to bid than those with no competitive advantages.

The first column of Table 6 shows results for the probability of winning conditional on bidding using a general probit model. The results indicate that incumbents bidding in their own division are more likely to win than any other bidder. Incumbents bidding in different divisions are also likely to win, but less than incumbents who are winning in their own divisions, compared to any type of contestants. There is no statistical difference between contestants winning conditional on bidding in their own divisions compared to contestants winning conditional on bidding in different divisions. As expected, these results support Jeitschko and Wolfstetter's (2002) first two theoretical predictions. Furthermore, efficient firms are more likely to win. This result supports Jeitschko and Wolfstetter's (2002) third theoretical claim. In addition, capacity-constrained bidders are less likely to win than capacity-unconstrained bidders. This is in accordance with the findings of Jofre-Bonet and Pesendorfer (2000a,b) and De Silva et al. (2002). Spatially adjusted probit results indicate that λ is insignificant. Both models show that bidders with potential synergies and competitive advantages are more likely to win conditional on bidding than those with no competitive advantages.

Table 7 presents the next set of regression results using an OLS model with White-corrected standard errors to correct for heteroscedasticity (column 1) and Gibbs sampling Bayesian heteroscedastic spatial error models (column 2). In OLS and spatially adjusted models, the results indicate that incumbents bidding in their own division or in different divisions bid more aggressively than any other bidder. This again supports the hypothesis that bidders who stand to realize synergies will bid more aggressively and also supports Jeitschko and Wolfstetter's (2002) general theory. In addition, the claim of Jofre-Bonet and Pesendorfer (2000a,b) and De Silva et al. (2002)—that capacity-constrained bidders are less likely to bid than capacity-unconstrained bidders—is supported.

TABLE 7

Regression Results for Log of Bids

Variable	OLS	Adjusted for Spatial Correlation
Constant	0.6370* (0.0636)	0.5583* (0.0385)
Project-1	−0.0472* (0.0180)	−0.0276* (0.0142)
Project-2	−0.0572 (0.0466)	−0.0104 (0.0256)
Project-3	−0.0705* (0.0184)	−0.0416* (0.0140)
Project-4	−0.0361 (0.0203)	−0.0240 (0.157)
Project-5	0.1094* (0.0423)	0.1230* (0.0381)
Project-6	−0.1808* (0.0225)	−0.1601* (0.0175)
Log of engineer's estimate	0.9643* (0.0044)	0.9700* (0.0027)
Log number of bidders	−0.0244* (0.0078)	−0.0302* (0.0058)
Log of firm's backlog	0.0116* (0.0015)	0.0093* (0.0011)
Firm's winning to bidding ratio	−0.1565* (0.0263)	−0.1476* (0.0189)
An incumbent who is bidding in his own division	−0.1266* (0.0244)	−0.1084* (0.0171)
An incumbent who is bidding in a different division	−0.1116* (0.0245)	−0.0942* (0.0169)
A contestant who is bidding in his own division	0.0002 (0.0168)	−0.0074 (0.0113)
λ		0.2857* (0.0866)
Number of observations	5221	5221
R^2	0.9731	0.9886

Note: Heteroscedasticity corrected SEs in parentheses.
*Denotes 95% statistical significance.

Finally, the study uses a fixed-effects model to analyze the data. To observe within-firm effects, only firms with multiple bids have been used. In the fixed-effects models, *wbratio* is excluded because the backlog variable is used to capture bidder efficiency due to capacity constraints over time. Furthermore, a firm may bid as an incumbent in its own division as well as in a different division, simultaneously. In this case, *wbratio* will be the same. The incumbent and contestant dummies are expected to show differences in the aggressiveness of bids. Again, one should remember that incumbency is not permanent. The results indicate that when a firm is an incumbent and bidding in its own division, it bids more aggressively than when it is an incumbent and bidding in a different division or when it is a contestant bidding in its own division or in a different division (Table 8). This again supports the first two theoretical claims of Jeitschko and Wolfstetter (2002). Finally, in all models the results indicate that when a firm is capacity constrained, it will bid less aggressively than when it has low capacity constraints. In the fixed-effects model, λ is insignificant, indicating that spatial dependence dissipates when looking at within-firm effects.

V. SUMMARY

This article examines the bidding behavior of firms with potential synergies in recurring spatially correlated road construction procurement auctions held by ODOT from January 1997 to August 2000. The study reveals that projects are spatially correlated, and as the distance increases, the correlation dissipates. The theoretical predictions indicate that incumbents with anticipated synergies will bid more aggressively than contestants. Firms with competitive advantages and inherent firm efficiencies will also bid more aggressively. Incumbent bidders bidding in their own divisions with expected synergies and competitive

TABLE 8
Fixed Effects Regression Results for Log of Bids

Variable	Unadjusted for Spatial Correlation	Adjusted for Spatial Correlation
Constant	0.8146*	−0.0005
	(0.0478)	(0.0027)
Project-1	−0.0468*	−0.0256*
	(0.0187)	(0.0149)
Project-2	−0.0154	−0.0230
	(0.0279)	(0.0258)
Project-3	−0.0146	−0.0084
	(0.0196)	(0.0160)
Project-4	0.0082	0.0114
	(0.0204)	(0.0156)
Project-5	0.1131*	0.1615*
	(0.0402)	(0.0366)
Project-6	−0.0441	−0.0344
	(0.0328)	(0.0269)
Log of engineer's estimate	0.9461*	0.9546*
	(0.0035)	(0.0029)
Log number of bidders	−0.0287*	−0.0279*
	(0.0079)	(0.0059)
Log of firm's backlog	0.0048*	0.0042*
	(0.0013)	(0.0100)
An incumbent who is bidding in his own division	−0.0694*	−0.0536*
	(0.0206)	(0.0154)
An incumbent who is bidding in a different division	−0.0424*	−0.0380*
	(0.0198)	(0.0151)
A contestant who is bidding in his own division	−0.0160	−0.0178
	(0.0157)	(0.0123)
λ		0.1917
		(0.0964)
Number of observations	5161	5161
R^2	0.9771	0.9810

Note: SDs in parentheses.
*Denotes 95% statistical significance.

advantages tend to have a high probability of winning conditional on bidding than other bidders. Firm efficiencies increase the probability of bidding and winning and also the aggressiveness of bids. These findings support the theoretical findings of Jeitschko and Wolfstetter (2002). Furthermore, the article shows that capacity constrained bidders bid less aggressively. Finally, the study shows that when considering within-firm effects, the results indicate a similar pattern. That is, when a firm is an incumbent bidding in its own division, it tends to bid more aggressively than when it is a contestant.

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