Single Bidders and Tacit Collusion in Highway Procurement Auctions

David Barrus
Department of Economics
Brigham Young University-Idaho
Rexburg, ID 83460-0815

Frank Scott
Department of Economics
University of Kentucky
Lexington, KY 40506-0034

January 2013

Abstract:

Collusion in auctions may take different forms, one of which is refraining from bidding. Such behavior may be overt or tacit. Prosecution of bid rigging in highway procurement auctions dominated federal antitrust activity in the 1980s. During the past decade, however, the major concern over competition has been the increasing number of single-bidder auctions. In Kentucky, Maine, and Mississippi, the proportion of single-bid contracts in asphalt resurfacing auctions has approached 80 percent. Certain elements of the institutions of highway procurement auctions facilitate collusive outcomes, namely, publicly available information, small number of potential bidders, and repeated interactions. An additional factor in Kentucky that creates a potential focal point for tacit collusion is that 60 percent of the state's 120 counties are served by a single asphalt plant, and the state delineates almost all asphalt paving jobs by county lines. In this paper we collect data on all asphalt paving auctions conducted by the Kentucky Transportation Cabinet during the years 2005-2007, and estimate bidding functions for each of the 31 firms licensed to bid on state and federal jobs. We include variables that affect the firm's cost of carrying out the work. We also include variables that capture competitive and strategic effects—most importantly we determine the potential service area of each asphalt plant in the state and use that information to determine the potential bidders for each asphalt project during the sample period. Our empirical results identify (1) regions of the state with numerous potential and actual competitors where bidding is highly competitive, (2) regions with only one firm and commensurately elevated bids, and (3) regions with two or three potential competitors but where firms refrain from bidding across county lines, resulting in single-bidder auctions with prices approaching monopoly levels.

People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices.[1]

I believe that my theory of oligopoly is a useful tool for this study, precisely because it seeks to isolate the determinants and forms of successful collusion—or rather, the determinants of successful cheating and hence unsuccessful collusion. The argument turns on the problem of getting reliable information on the observance of collusive agreements.[2]

Introduction

Understanding firms' attempts to collude drives much of economists' study of oligopoly. Detection and deterrence of collusion are perhaps the primary challenges of antitrust policy.[3] In auction markets collusion has attracted less attention than a general focus on design mechanisms and other factors affecting the competitiveness of such markets.[4] Much of the attention that has been paid to collusion in auction markets has been motivated by price fixing and bid rigging conspiracies in public procurement auctions. Various methods have been proposed for detecting overt collusion in auction markets. As Harrington (2008), Porter and Zona (1993), and others have noted, however, refraining from bidding is one form that collusion may take. Such behavior may be overt, if it is the result of explicit communication among firms, or tacit, if it arises without overt behavior. While explicit agreements not to bid have been the object of study, we are not aware of any empirical analysis of tacit refusals to bid in procurement auctions.

After a decade where big monopoly cases dominated federal antitrust activity, in the 1980s enforcement energy shifted to price fixing. Collusion in public procurement auctions became a target area, especially in highway procurement auctions. There were hundreds of bid rigging prosecutions and convictions across the country.[5] Since then, state departments of transportation have aggressively monitored bidding behavior, and there have been relatively few §1 Sherman Act prosecutions since the 1980's. That does not mean that concerns over the competitiveness of highway bidding have gone away. Instead, the trend is toward single-bidder auctions, with resulting higher prices for public transportation projects.[6]

Single-bidder auctions may arise innocently or collusively. And if collusively, the collusion may be tacit or overt. Bid rigging schemes can take on a variety of forms. Sometimes all participants in the auction are part of the conspiracy, and then the problem becomes determining which conspirator will win the auction and how other conspirators will be compensated. Things change somewhat if non-conspirators participate in the auction. Accommodating behavior by co-conspirators can take the form of submitting complementary bids above (in a highway procurement auction) the predetermined winner's bid. Alternatively, co-conspirators can simply refrain from bidding. Either way, if the collusive behavior is overt then it violates the federal antitrust laws in the U.S.[7]

A major challenge in collusive bid rotation schemes is determining which cartel member gets to win each auction. A variety of schemes have been uncovered in antitrust enforcement, such as . . . When multiple firms are involved, an explicit agreement with direct communication is often the only viable way to work out the details necessary to keep all cartel members happy and on board. When the

---

[1] Smith (1776), Book I, Ch. X, Part II.
[2] Stigler (1968), p. 268.
[3] Porter (2005), p. 147.
[4] See, for example, Klemperer (2004).
[5] GAO (1990): http://archive.gao.gov/d22t8/142779.pdf
[6] AASHTO/FHWA Survey on Construction Cost Increases and Competition, April 2006.
[7] Werden (2004) extensively discusses modern oligopoly theory and the definition and proof of collusive agreements under the antitrust laws.

number of potential bidders is small, however, firms may recognize their mutual self interest in suppressing competition without direct communication.[8] The existence of a natural focal point may obviate the need for overt collusion. If procurement auctions are configured so as to create an easy way for firms to allocate contracts and refrain from bidding against one another without openly communicating, then tacit collusion may accomplish the same outcome as would occur under an illegal cartel.

The difference that a second bidder makes in highway procurement auctions is sizable. As can be seen in Table 1, in Kentucky during the 2005-07 period sixty-three percent of asphalt paving projects only had one bidder, and ninety percent had one or two bidders. Winning bids for single-bid asphalt projects averaged 2.22 percent over the state highway engineer's estimate of the cost of the job. Winning bids when there were two bidders averaged 13.35 percent below the engineer's estimate, and with three bidders the low bid was 16.73 percent below the engineer's estimate. It is clear that firms in single-bid auctions exercise monopoly power and are able to raise bids above the competitive level. The nearly 16 percent difference made by a second bidder cost Kentucky taxpayers nearly $100 million of the $608 million spent on paving contracts during 2005-07.

Our goal is to understand the nature of bidding in highway procurement auctions for asphalt paving projects. The underlying question is whether so many auctions attract only a single bidder because rival firms are coordinating their bids. We start by reviewing the history of bid rigging in the asphalt industry and methods used to detect collusion in auctions. We discuss how the mechanics of highway procurement auctions and economic aspects of asphalt paving create a bidding environment that facilitates coordination in the repeated bidding game that rival contractors engage in. We then determine feasible service areas for all asphalt contractors in Kentucky, and estimate their bidding functions to see what factors influence the decision to bid. We find that, in many parts of Kentucky, county boundaries create a natural focal point for bidding that helps firms solve their repeated coordination game by refraining to bid in rival firms' territories. We conclude the paper by discussing policy options that might increase competition in auctions by making such coordination more difficult.

Bid Rigging in the Asphalt Industry

During the period of analysis in this paper, there is no evidence of overt collusion in Kentucky, nor is there any suspicion of illegal activity. Since that has not always been the case, a brief overview of past overt collusion in highway procurement auctions is warranted. Antitrust enforcement changed significantly when Ronald Reagan became President in 1981. The U.S. Department of Justice ended a 13-year-old monopoly case against IBM and negotiated the breakup of AT&T. The focus of antitrust prosecution switched from large monopoly cases to prosecution of price fixing and collusion.[9] A pattern of highway bid rigging was uncovered in Tennessee and found in other states. In Tennessee contractors would gather in a Nashville hotel the night before bid lettings to determine who would be the winning (low) bidder. Other contractors would submit complementary (higher) bids, in return for payoffs from the winner or the promise of being the low bidder in a future auction (rotation of low bidders).[10] By

[8] As Fraas and Greer (1977, pp. 29-31) point out, the necessity of a formal collusive agreement increases as structural conditions become more adverse to tacit cooperation. With two firms selling a standardized product overt collusion may be immanently possible but not really needed. Their empirical analysis of 606 explicit price fixing cases from 1910 to 1972 confirms this conjecture.

[9] Rosewicz, Barbara. 1984. "New Antitrust Chief Says He's as Tough as Predecessor," *United Press International.* accessed March 10, 2010,

[10] Sniffen, Michael J. 1982. "Highway Bid-Rigging Investigation Expanded to Five New States," *The Associated Press.* accessed March 10, 2010,

1984 the federal investigation of highway bidding had expanded into 29 states, with 181 corporations and 189 individuals pleading guilty, 21 corporations and 25 individuals being convicted at trial, and 16 corporations and 22 individuals being acquitted.[11] In all, there were over 600 highway bid-rigging cases during the 1980s.[12]

Since the 1980s the Department of Justice has changed its focus away from bid rigging, in no small part because of a general belief that overt collusion occurs less frequently due to the heavy prosecution during the 1980s and better methods, such as wiretaps, for detecting bid rigging. This is not to say, however, that highway procurement auctions are highly competitive.[13] In an August 2005 meeting of the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Construction, the committee identified single-bid contracts and decreasing competition as major concerns. According to a survey commissioned by AASHTO (2006) the average number of bidders per project declined from 4.24 in 2002 to 3.36 in 2005. For Kentucky the average number of bidders declined from 2.94 in 2002 to 2.18 in 2005. Two major reasons cited by departments of transportation for the decline of bids were industry consolidation and increased work with the same number of contractors. Data from Kentucky, however, indicate that industry consolidation was not a problem—during 2005-2007 the average number of projects per firm was 10.4 in Kentucky, while the average from 1994-2007 was 11.2 projects per firm.

Of particular concern to AASHTO and the Federal Highway Administration are projects with only one bidder, an increasing phenomenon during the time period of 2002-2005. As is evident in Table 1, single-bid contracts are more prevalent in asphalt resurfacing projects than other highway construction or maintenance projects. The three states with the highest percentage of single-bid contracts are Kentucky, Maine, and Mississippi.[14] Discussions with an official in the Kentucky Transportation Cabinet reveal that single bids are a concern and occur primarily in rural areas. Maine officials indicate that their single bids are spread throughout the state.[15] In Montana 70 percent of urban projects receive only one bid.[16] This lack of competition, particularly in Kentucky, does not come from industry consolidation or increases in projects. These facts motivate this analysis. The question remains whether the high level of single-bid contracts represents an efficient equilibrium or is the result of tacit collusion.

Detecting Collusion in Auctions

Concomitant with increased focus on price fixing and bid rigging by federal antitrust investigators in the 1980s, economists began paying greater attention to cartels and worked to develop

---

[11] Sniffen, Michael J. 1984. "Federal Highway Bid-Rigging Probe Expands into 29th State," *The Associated Press.* accessed March 10, 2010,

[12] Ryan, Sean. 2004. "Wisdot Seminar Draws 270," *The Daily Reporter* Milwaukee, WI. accessed March 10, 2010.

[13] Hershey, Robert D. Jr. 1988. "Tougher Antitrust Stance Expected," *The New York Times.* New York, NY: 1, accessed March 10, 2010,

[14] The average number of single-bid projects among the surveyed states is 20 percent. According to the survey, 70 percent of all asphalt resurfacing projects in Kentucky attract only a single bidder. Data calculated for this analysis indicate that the average proportion of single-bid contracts from 2002-2005 in Kentucky was 62 percent in asphalt paving. It rises to 63 percent from 2005-2007. It is around 80 percent for both Maine and Mississippi.

[15] Officials in Mississippi indicate that "single bids are not an issue. They have historically occurred in certain areas of the state." Source: AASHTO. 2006. "Aashto / Fhwa Survey on Construction Cost Increases and Competition," http://www.fhwa.dot.gov/programadmin/contracts/priccomp.cfm.

[16] Officials in Montana state that "Montana has more paving contractors and the contractors who are willing to bid on urban jobs are not very mobile. Therefore we typically only get one or two bids for urban jobs and the prices are typically higher than they should be." 30% of all asphalt resurfacing projects in Montana are single bids. Source: AASHTO, 2006.

methods to identify collusive behavior. Feinstein et al. (1985) theoretically and empirically analyze information asymmetries between highway construction cartels and the states that purchased their services. Their results indicate that cartels seek to influence engineer's cost estimates through misinformation. They find that cartels actively fed the purchaser misinformation in order to change the purchasers' (the state) expectation on what constitutes a "good buy." Porter and Zona (1993) develop an econometric test to detect bid-rigging in highway procurement auctions. They focus specifically on auctions where there were more than two bids, and attempt to detect "phantom" bidding. A phantom bid is a bid that looks competitive because multiple firms are bidding, however, the identities of the low and high bidders are determined by the participating firms before the bids are submitted. This overt collusion gives the appearance that numerous firms are competing for a project, but the reality is the winner of the bid is predetermined.

Bajari and Ye (2003) develop econometric tools to detect collusive behavior and empirically analyz data on highway seal-coating contracts in Minnesota, North Dakota and South Dakota. They incorporate cost asymmetries among bidders in their model. Cost asymmetries arise due to locations of firms, capacity constraints, and knowledge of local rules and regulations. They test for conditional independence to see if bids are independent and exchangeability to see if costs and not just the presence of competitors are actually driving bid levels. Lastly, they take into account industry experts' opinions about realistic distribution of markups to see if the market is competitive or collusive.

McAfee and McMillan (1992) theoretically analyze bidding rings and explain how weak cartels and strong cartels function and maintain their collusive behavior.[17] Cartels may use a mechanism such as "phases-of-the-moon" to determine who will win a particular auction bid. Also, there must be the ability to enforce the collusive behavior if there is deviation. They find that all members of a weak cartel submit the same bid, whereas in a strong cartel members can make transfer payments and not allow new entrants into the market.

The literature on collusion in auctions has also extended into other sectors including credit cards, hotels, electricity, timber, and the dairy industry. Knittel and Stango (2003) analyze tacit collusion in the rates charged by credit card issuers. They find that price regulation created a focal point that allowed tacit collusion that disappeared with deregulation of credit card prices. Gan and Hernandez (2011) analyze tacit collusion in the hotel industry. They use a switching regression model and find that clustered hotels are colluding during off-peak times. Fabra (2003) theoretically models tacit collusion in uniform-price and discriminatory auctions in a repeated setting which allows the firms to sustain collusive behavior. She focuses on the electricity industry in England and Wales. Price (2008) extends Bajari and Ye's (2003) model into timber auctions in British Columbia and incorporates the spatial distribution of bidders to detect collusion. He finds evidence that perfectly competitive bidding patterns do not always exist when geographic space is accounted for. As distance between firms increases, bidding behavior becomes more competitive. Research has also focused on bid-rigging in school milk procurement auctions during the 1980s and 1990s. Pesendorfer (2000), Porter and Zona (1999), Lanzillotti (1996), and Scott (2000) analyze bid-rigging in Florida and Tennessee, Ohio, and Kentucky respectively.

Other authors focus on factors that influence whether and why firms bid on highway procurement projects. Li and Zheng (2009) use a semi-parametric Bayesian method to estimate distribution of entry cost, bidder's cost and controls for unobserved heterogeneity. They find that increases in the number of potential bidders for highway mowing projects in Texas can lead to less aggressive bidding behavior and higher expected procurement costs because the cost of entering ("*entry*

---

[17] Side payments are possible among members of a strong cartel, but are not possible in a weak cartel.

effect") is greater than the "*competitive effect"*.[18] The authors could not rule out collusion as the motivation behind this outcome, but they did not investigate it. Hong and Shum (2002) investigate the "winner's curse" using data from New Jersey (1989-1997). They focus on three categories of projects: highway work, bridge construction and maintenance, and road paving. They find that non-paving jobs and bridge repair average costs rise as competition increases.[19] In contrast, for projects such as asphalt paving, firms have no uncertainty about costs for completing the project. They explain that firms which have overly optimistic information about the value of these non-paving jobs and win the bid may end up with negative expected profits (*winner's curse*). Therefore, a rational firm will not bid as aggressively if there are more competitors (*winner's curse effect*).[20]

De Silva et al. (2003) analyze bidding patterns of entrants and incumbents and find that entrants bid more aggressively than incumbents. They also find that past winning and capacity constraints all impact firms' bidding behavior. They do not find a strong relationship, however, between distance and bidding behavior. Jofre-Bonet and Pesendorfer (2003) analyze repeated auctions and focus on how capacity constraints and firm efficiencies impact bidding behavior in California. They find that capacity constraints can increase costs to a firm. De Silva et al. (2005) analyze how winning one auction will increase the likelihood of winning another auction due to synergies associated with the projects in a dual-day auction. We draw from this literature and use some of these factors, including distance and capacity constraints, in creating bid functions in this paper.

Other research on highway procurement auctions focuses on how to account for unobserved heterogeneity in analyzing highway procurement auctions (Elena Krasnokutskaya, 2011), how time incentives impact construction project completion in Minnesota (Bajari and Lewis, 2009), and how bid preferences and discounts for small businesses impact behavior of large business bidding behavior in California (Krasnokutskaya and Seim, 2010 and Marion, 2007). Two papers find that making the engineer's cost estimate publicly available before the bid decreased the average bid level in Oklahoma (De Silva, Dunne, Kankanamge, and Kosmopoulou, 2008 and De Silva, Kosmopoulou, and Lamarche, 2009).

Highway Procurement Auctions

Certain elements of the institutions of highway procurement auctions facilitate collusive outcomes. Political and geographical factors create a market environment that helps firms engage in tacit collusion. Since the approach taken by the Kentucky Transportation Cabinet (KYTC) to procure construction and maintenance work is generally representative, we will use it as an example. The high number of single-bid contracts grows out of the method Kentucky uses in soliciting bids and awarding contracts. There are many different types of projects to be carried out, ranging from constructing new roads, resurfacing existing roads, trimming trees and mowing grass, maintaining and replacing bridges,

---

[18] This is a result of an "*entry effect*" and a "*competitive effect*", where the "*entry effect"* is where firms bid less aggressively with more firms and cause procurement costs to rise. Since firms realize their chances of winning a bid decrease with additional firms and it is costly to prepare a bid, firms choose to bid less aggressively. If the "*entry effect*" is greater than the "*competitive effect*" then bids will actually rise with more potential bidders. The authors find that in auctions for mowing jobs, with more potential bidders the "*entry effect*" dominates the "*competitive effect*".

[19] These types of projects have common cost uncertainty where a firm is not always clear how much a bridge project will cost, and different firms may have different expectations of these costs.

[20] An additional competitor lowers the bids (*competitive effect*) and firms' expectation of negative profits increases (*winner's curse effect*) as additional firms enter the bidding. If the *winner's curse effect* is larger than the *competitive effect* then bid levels can actually increase as more firms enter.

building fences, and painting lines.[21] Of particular importance is that when certain funds are used it is required to separate funds by county.[22] Funding on roadway projects is separated by county, therefore KYTC usually separates projects by county.

For reasons that will be discussed below, our primary interest in this analysis is asphalt paving projects. Major asphalt jobs originate from a comprehensive full planning process, are attached to a Six-Year Plan and State Transportation Improvement Plan, and are approved by the state legislature. Minor, routine asphalt resurfacing projects are typically initiated within the KYTC and do not need to be approved by the legislature. The vast majority of the projects that were analyzed for this paper are minor resurfacing projects.[23]

In Kentucky, projects are let on a monthly schedule, but this can vary from State to State. In most States each project is advertised for a certain period of time, bid proposals and plans are available for purchase, and then bids are submitted. Most states require that contractors working for them must be prequalified and also require that bid proposal and/or project plans must be purchased.[24] In Kentucky the project must be advertised between 7 to 21 days before the project is to be let. Firms must purchase a bid proposal to be eligible to bid on a project. The bid proposal costs $10 and the names of firms which purchase bid proposals are publically available the Friday before the bids are opened.[25] Before 2008, a firm could ask to have their company name not included on the publically available bid proposal list.[26]

All firms in Kentucky must be pre-qualified by the transportation cabinet and the list of pre-qualified firms is publicly available. Care is taken by the transportation cabinet that a contractor does not take on too much work, and officials hold meetings with all potential contractors on projects scheduled for the upcoming year to determine the letting schedule. Projects are moved around on the calendar in order to accommodate potential contractors.

Sealed bids are opened and read aloud once a month at the Kentucky Transportation Cabinet. The KYTC then analyzes the bids for 10 days before awarding a contract. The bids are analyzed to see if the bid is unbalanced, front-loaded, or if there is any indication of collusion.[27] The transportation cabinet looks at the overall total of each bid and compares it to the state highway engineer’s estimate. In some states the engineer’s estimate is available before the day of bidding, while in other states like

---

[21] In 2006 Kentucky spent $1.7-1.8 billion on transportation related projects. Sixty-three percent came from the State Road Fund and thirty-one percent was supplied by federal allocations.

[22] A KYTC transportation official stated that for certain types of projects designated “rural secondary” the money must go to the specific counties.

[23] Source: Kentucky Transportation Cabinet. 2010a. "2010 Recommended Highway Plan," K. T. Cabinet, Frankfort: Kentucky Transportation Cabinet, http://transportation.ky.gov/highways/.

[24] Anderson, S. D.; Byron C. Blaschke; National Cooperative Highway Research Program.; American Association of State Highway and Transportation Officials. and National Research Council (U.S.). Transportation Research Board. 2004. *Statewide Highway Letting Program Management*. Washington, D.C.: Transportation Research Board.

[25] A contractor can purchase a bid proposal up until 3:00 pm the day before the bid opening. Source: ibid.

[26] After 2008, a company was no longer allowed to have their company name removed from the bid proposals. The purchasing of bid proposals was replaced in 2010 by a bidder registration form. A firm still must fill out the form for the projects they are going to bid on. It is still due at 3:00 pm the day before bids are opened. The list of eligible bidders is still published before the bids. Source: Construction Procurement, Kentucky Transportation Cabinet http://transportation.ky.gov/contract.

[27] Kentucky and other states use the American Association of State Highway and Transportation Officials (AASHTO) Transport System which is a program that is used to detect collusion. It can compare the bids to the engineer’s estimate, the other contractors who bid, and also create reports on past bidding behavior, market prices, and price differences according to various parameters such as geography .

Kentucky it is not available until after bids are opened. An informal rule in Kentucky is that if bid is 7 percent over the engineer's estimate it should be rejected, however this rule is infrequently followed. If everything is judged by KYTC to be reasonable then the project is awarded, even if there is only one bidder.

Economic Aspects of Asphalt Paving

We focus on asphalt paving and do not consider other types of projects such as grade and drain, bridge work, mowing, etc. The important element of the asphalt paving process is the time constraint, which limits how far away from a plant a particular firm can bid—the firm's feasible service area. Projects farther away from a plant result in higher costs to the firm because asphalt is heavy and hence costly to transport. As a result, the geographic scope of the market for asphalt projects is much smaller than geographic market scope for road and bridge construction, mowing, and other highway maintenance projects. Other factors relevant to asphalt production and paving are high start-up costs (some of which take the form of environmental permits), economies of scale at the plant level, potential problems of obtaining aggregate (sand and gravel), and the fact that hot-mix asphalt must be compacted while it is very hot. These factors influence the competitive landscape faced by asphalt contractors bidding in procurement auctions.

The process of paving a road begins with the extraction of rock (aggregate) from a quarry and the distillation of asphalt cement or bitumen from crude oil. The cost of producing asphalt varies as the prices of aggregate and asphalt cement vary. These two components are combined at high temperatures at an asphalt plant when asphalt cement is in liquid form. The resulting hot-mix asphalt is dispensed into trucks and driven to the project site. Care has to be taken to not let the mixture cool too much before compaction. It must be laid and compacted before the temperature of the mixture falls below 85°C (185°F). Below this temperature the asphalt starts to crack and will not set properly.[28]

Transportation of the hot-mix asphalt from the plant to the project site is another significant cost. The trucks are often insulated and the bed is usually covered with a tarp. A general guideline is that hot-mix asphalt has 2 to 3 hours in an insulated truck before it becomes too cool.[29] However, an official of the Kentucky Transportation Cabinet stated that a more realistic time is between 45 to 60 minutes from the time the hot-mix asphalt is dispensed to when it is compacted. This time frame is critical in determining the extent of a firm's feasible service area. The calculation of feasible service areas is important in the analysis of tacit collusion, and is discussed further in the Data section.

Coordination of Bidding in a Repeated Game

There is considerable variation in the bidding environment faced by different asphalt paving firms in Kentucky. Northern Kentucky and the greater Louisville area are large urban markets, and can support multiple asphalt companies. In addition to dense public road networks, there is considerable commercial demand for asphalt paving and so the market environment is very competitive with multiple firms. In eastern Kentucky, the market is much thinner, because of sparse population and negligible commercial paving demand. Since the 1980s, the region has been served by one multi-plant firm, which operates each of its plants on a rotating basis with transient plant and paving crews. The market environment resembles natural monopoly, in that there only seems to be enough business to support one efficient-sized firm.

---

[28] See Appendix A-1 for a schematic of the asphalt paving "train."

[29] AASHTO; National Research Council (U.S.). Transportation Research Board.; United States. Army. Corps of Engineers. and United States. Federal Aviation Administration. 2000. *Hot-Mix Asphalt Paving Handbook 2000*. Washington, D.C.: US Army Corps of Engineers.

In many other parts of the state the demand for asphalt paving is sufficient to support geographically dispersed oligopolists with overlapping feasible service territories. It is in this type of market environment that strategic interactions among firms become important. The prevalence of these oligopoly/duopoly markets can be seen in Figure 1, which illustrates every asphalt plant in Kentucky approved to bid on state contracts. As can be seen, 31.7 percent of the 120 counties in Kentucky do not have an asphalt plant located within the county, 60.0 percent of counties have one plant, and 8.4 percent have more than one plant within the county.

Bidding in a competitive environment has been thoroughly discussed by other authors. We will have little to add, except to use competitive areas as a benchmark for comparison. Bidding under natural monopoly is straightforward: how high can a firm bid and not get rejected by KYTC?[30] Oligopoly bidding gets interesting—how to determine who should win a particular auction, how to rotate winners, and how the designated losers should bid, if at all?

This bidding scenario thus has elements of a coordination game, a coordination game played repeatedly, where the Nash equilibrium coordination requires either side payments or rotation of winners. Side payments are by definition overt and illegal. Complementary bids and refraining from bidding are illegal if firms directly and overtly agree to pursue such strategies. Refraining from bidding generally is not illegal if a firm unilaterally decides that such a strategy is in its own best economic interest.[31]

The global profit maximum for all players occurs when the low-cost firm for each project wins the auction. If each player wins often enough so as to consider the outcome equitable, then the only problem is devising a bid rotation scheme where the low-cost firm is always the designated winner. With multiple firms and multiple projects, overt communication may be required to reach this outcome.[32] When only two firms are involved, however, tacit collusion may be sufficient. The existence of a focal point can greatly facilitate players' abilities to solve the game. Since distance plays such a large role in firms' costs, a natural assignment algorithm would designate the closer of the two firms to win the bid.[33]

The problem can be modeled as follows. Consider two firms, X and Y, who produce a product that is costly to deliver and who are located at some distance from each other. They can bid on a project that is located distances d_x from X and d_y from Y. Each incurs production and transportation costs of C_x and C_y, respectively, if they win the bid and carry out the project. There is a random element of ε associated with each firm's costs, so that neither knows its own or its rival's costs with certainty ex ante. The following diagram illustrates this scenario:

Firm X   Project #1   Firm Y
|__________d_x________|____________________d_y____________________|

[30] There are numerous examples of single-bidder paving companies playing "chicken" with the KYTC, having an initial bid rejected and the project being put up for rebid. On several occasions there have been three and four rounds of rejected bids and rebidding. The usual outcome is that the KYTC ultimately blinks when there is no viable alternative supplier.

[31] Werden's (2004) discussion of the legal status and treatment of tacit vs. overt collusion is very helpful. See especially pp. 734-759. Yao and DeSanti (1993) also discuss the legal quandaries of prosecuting tacit collusion.

[32] This is precisely the scenario studied by Porter and Zona (1993), whereby highway contractors on Long Island devised a bid rotation scheme with designated losers submitting complementary bids.

[33] Reference papers that discuss distance as an identifying device.

There are three possibilities: (1) $d_x < d_y$ such that $|C_x - C_y| > \varepsilon$, i.e. firm X is considerably closer and so has a clear cost advantage; (2) $d_x > d_y$ such that $|C_x - C_y| > \varepsilon$, i.e. firm Y is considerably closer and so has a clear cost advantage; and $d_x \approx d_y$ such that $|C_x - C_y| < \varepsilon$, i.e. firms X and Y are roughly equidistant and so neither firm has a clear cost advantage.

Suppose firms X and Y bid on Project #1 in a one-shot game where firm X has a clear cost advantage, i.e. condition (1) above holds. Let us restrict bid options for each firm to bidding competitively (P_c) or bidding monopolistically (P_m). Since firm X has a clear cost advantage, it will always win if both firms bid competitively.[34] The payoff matrix for this game is:

		Firm Y	
		P_c	P_m
Firm X	P_c	π_c , 0	π_c , 0
	P_m	0 , π_c	π_m , 0

Without digressing into a deeper discussion of economic profits, let us assume that winning the auction when bidding is noncompetitive yields more profit (π_m) than winning when bidding is competitive (π_c). Either is better than not winning the auction ($\pi = 0$).

The Nash equilibrium to this game is that both firms bid competitively, firm X has the lower bid due to its locational cost advantage, and it then earns competitive profits on the project. Likewise, because of symmetry, if firm Y has a significant locational advantage in a one-shot game it would win the bid and earn competitive profits.

The third possibility is that the project is roughly equidistant from each firm, so that neither has a clear cost advantage. The payoff matrix for this game is:

		Firm Y	
		P_c	P_m
Firm X	P_c	$\frac{1}{2}\pi_c$, $\frac{1}{2}\pi_c$	π_c , 0
	P_m	0 , π_c	$\frac{1}{2}\pi_m$, $\frac{1}{2}\pi_m$

where the payoffs on the diagonals represent expected profits if both take the same bidding strategy and random elements determine who actually wins the auction. If $\frac{1}{2}\pi_m > \pi_c$, then this payoff matrix has the form of a traditional coordination game, and there are two Nash equilibria to the game, with the strategy pair (P_m , P_m) clearly dominating.

In actuality many asphalt paving firms in Kentucky play this game repeatedly against an identifiable rival, with the KYTC putting projects up for bid in various locations at regular intervals. If roughly half the projects put out for bid were clearly closer to firm X and the other half were clearly closer to firm Y, then it would not be surprising at all if the two firms used distance as a focal point for cooperation and bid noncompetitively, with the more distant firm's noncompetitive bid being higher than the closer firm's noncompetitive bid. The payoff matrix to this repeated game would resemble that immediately above, and the dominant Nash equilibrium would be characterized by noncompetitive bidding by each firm.

Projects roughly equidistant from both firms create a problem for such coordination, however, and so relying solely on distance as a focal point for cooperation may give rise to outbreaks of competitive bidding or temptations to overtly collude. Fortunately for asphalt oligopolists (and

[34] Let us assert that firm X also wins if both firms bid noncompetitively, since its bid will be lower than firm Y's if both use the same relative markup.

unfortunately for Kentucky taxpayers), the KYTC refines this focal point by assigning asphalt projects strictly according to county boundaries. In adjoining counties where there is only one company with an asphalt plant in each county, the natural focal point outcome is hard to miss.

The different possible bidding scenarios can be seen in the following four diagrams. Figure 2 illustrates a project located in county A where firm X is the only firm with an asphalt plant in that county. Figure 3 illustrates a project located in adjacent county C where rival firm Y is the only firm with an asphalt plant. Figure 4 illustrates a project located in county A where both firm X and rival firm Z have asphalt plants. Figure 5 illustrates a project located in adjacent county B where neither firm X nor firm Y has an asphalt plant.

Projects #1 and #2 in Figures 2 and 3 are roughly equidistant from both firm X and firm Y. In a "flat" world, each firm would have similar costs of carrying out each of the two projects. With no focal point for cooperation, it is not clear how the two firms reach a noncompetitive bidding equilibrium without overt communication. If projects are delineated by county lines, however, and each firm is the sole supplier of asphalt in its own county, then the natural focal point for cooperation is for firm X to carry out project #1 and firm Y to carry out project #2, both at noncompetitively high bids.

Figures 4 and 5 illustrate situations where there are no natural focal points for cooperation. In Figure 4 rival firms X and Z both have asphalt plants in County A. Project #3 is also located in County A, and is roughly equidistant from both firms. With no clear focal point to guide the firms' cooperative instincts, competitive bidding is likely absent overt communication between the firms. In Figure 5 rival firms X and Z have asphalt plants in Counties A and C, respectively. Project #4 is located in County B, which is adjacent to both Counties A and C and has no asphalt plant located within its boundaries. Project #4 is also roughly equidistant from the asphalt plants of both X and firm Y. Again there is no clear focal point for cooperation, and without overt collusion the bidding is likely to be competitive.

Data

Source of Data

The purpose of our empirical analysis is to see if firms are coordinating bids. The data used are publicly available and were obtained from the Kentucky Transportation Cabinet for the years 2005-2007. Information on contracts awarded, which firms purchased bid proposals, which firms actually bid on each project, the amounts of each bid, the winning firm, and the engineer's estimate was obtained from the KYTC Construction Procurement website.[35] These detailed data were only available after 2005 on the KYTC website. Upon request, the Kentucky Transportation Cabinet supplied project location (latitude and longitude for the mid-point of each project) information for the projects in Kentucky from 1996-2009. These data also included information on the type of work including a short description of what the project entailed along with information about the road, location, and number of bids. This was supplemented with another data set from KYTC which contained all awarded contracts in Kentucky from 1994-2010.

Information about plant locations came from various sources including the Plantmix Asphalt Industry of Kentucky (PAIKY) website, the Division of Materials within the Transportation Cabinet, air quality permits obtained from the Division of Air Quality within the Environmental and Public Protection Cabinet, and from individual firm websites. For a few firms, the locations of the asphalt plants were confirmed by telephone. There are a total of 1,985 projects that were let and awarded from 2005-2007. We identified asphalt projects using the KYTC label for each project that briefly summarized the scope of the project. In order to qualify as an asphalt project, the job cannot have any other element except

[35] Only detailed information from 2005-2010 is available. Source: Construction Procurement, Kentucky Transportation Cabinet http://transportation.ky.gov/contract.

asphalt resurfacing, surfacing, rehabilitation, or patching. Asphalt projects that had grade and drain, bridge, or guardrail components were not included in the "asphalt" projects for this analysis, leaving us with 1,075 projects for analysis. These projects accounted for around $600 million in expenditures by the Kentucky Transportation Cabinet.

Firms and Counties

There are 31 major firms that bid on asphalt paving projects in Kentucky during the sample period.[36] Table 2 contains the names of the 31 firms, the number of asphalt plants each firm operates, the number of asphalt projects they bid on in Kentucky, the percentage of the those bids where the firm is the single bidder, the number of contracts the firm won, and the value of the contracted projects. Considerable variation exists across firms. In the far western corner of Kentucky, H&G Construction bid on 77 projects even though it only has one asphalt plant. They only won 14 of those projects, and they were never the only bidder, always facing competition from Jim Smith Contracting and Murray Paving on projects. Two firms, ATS Construction and Nally & Gibson Georgetown, won all of the projects they bid on.

The 31 Kentucky firms have a total of 113 asphalt plants in the 120 Kentucky counties for an average of 0.94 plants per county. In 60 percent of counties in Kentucky, there is only one firm with asphalt plants in the county. Thirty-two percent of the counties have no asphalt plants. In more urban areas such as Louisville there are two or three asphalt plants in the county. Figure 1 illustrates the location of each asphalt plant in Kentucky. The more rural areas typically have one asphalt plant per county. Urban areas such as Northern Kentucky and Louisville typically have two or more firms per county.

Service Areas

Political boundaries such as county boundaries and highway district boundaries do not necessarily align with geographic economic markets. In asphalt paving, the feasible service territory is the area where a firm can economically service any asphalt project, i.e. where the firm can reasonably complete an asphalt paving job without the hot-mix asphalt cooling below the temperature threshold. When looking at the distance from plants to projects for projects that firms bid on, there were no instances in the entire sample where a firm bid on a project more than 60 miles from its plant. The service area for every firm was thus set at 60 driving miles from each firm's asphalt plant.

All mapping analysis was done in the ArcGIS ArcMap program using the Network Analyst function.[37] We were able to determine and calculate the service areas and driving distances from asphalt plant to project. The software also mapped out these 60 mile service areas. Figure 6 shows H&G Construction's service area and the projects they bid and did not bid on in their service area. The different 10-mile bands indicate distance from their asphalt plant in Graves County. Notice in Livingston County they bid on a project that is almost 60 miles away from their asphalt plant.

---

[36] There were three additional Kentucky firms that showed up once or twice in the bid data, and four Indiana paving companies that were approved for state contract work and bid into Kentucky. One of the Indiana firms, Gohman Asphalt, is a frequent bidder in the Louisville market. We did not include any of these firms in the empirical analysis because of incomplete data.

[37] The ArcGIS ArcMap software by ESRI is mapping software. This software allowed us to map the asphalt plants and project locations. This was done by inputting the latitude and longitude of the plants and projects and the software mapped the location. The road map for Kentucky was obtained from the Kentucky Transportation Cabinet. The Kentucky map was uploaded into the software and used in all of the analysis. This map includes data indicating road length. The mapping software is able to calculate "as-the-crow-flies", driving distances, and other distance measures. The software can also be used to draw the shortest route from point "A" to point "B". It can also map distance circles outward from a certain point. These functionalities were used to create the feasible service areas.

All of the projects in each firm's individual service area are included in the analysis of bidding behavior. Each individual project located in a firm's service area is a unit of observation. Our goal is to understand why firms bid or do not bid on projects that they could feasibly carry out. Expected profits are the obvious starting point, so we analyze factors that are likely to affect the expected profitability of a project. These include cost factors such as distance from plant to project, the number of projects a firm has under contract, and the size of the project. Since firms are competing in a repeated game, strategic factors are also included. These variables include how many firms purchased bid proposals and how many rival firms also have the project in their service areas. Lastly, county variables are added to see if firms use county boundaries as focal points to coordinate their bidding.

Estimating Bid Functions and Identifying Tacit Collusion

Our goal is to investigate whether firms are using county boundaries as focal points for tacit collusion. To accomplish that, we estimate bid functions for each of the 31 firms in Kentucky. Previous authors (e.g. De Silva, Jeitschko, and Kosmopoulou, 2009) who have examined bidding in highway procurement auctions have combined all the data into one market bidding regression. This approach makes sense if each firm faces similar market conditions in a fairly thick bidding market. As we have argued, however, most Kentucky asphalt paving companies face bidding environments unique to themselves. For that reason, we estimate each firm's bid function separately to see what factors influence each individual firm's bidding behavior. Since Kentucky varies in geography and in market density, each firm deals with different factors in its specific service area, so we control for these economic and geographic factors by constructing firm-specific bid functions.

Each unit of observation is a project located within a firm's service area. The dependent variable is the behavior we are trying to understand—whether a firm bids on a project which it can feasibly carry out. As shown in Table 2, one firm only bid on 4 projects while another bid on 150 projects. Figure 6 illustrates for H&G Construction located in Graves County the projects they bid on and did not bid on in their service territory. Firms will bid or not bid based on their assessments of expected profitability. Expected profitability is determined by cost factors and competitive/strategic factors. We discuss each in turn.

Factors affecting the costs of carrying out a project will influence whether firm bids on a project. After determining projects falling within the firm's service area, we calculated the driving distance from the plant to the project using the OD Cost Matrix function in ArcMap. This mapping function calculates the shortest driving distance from a plant to each project in the service area using maps publicly available from the Kentucky Transportation Cabinet. Distance is a major determinant of costs, and so we would expect the distance variable to be highly important in the firm's bidding decision.

Capacity utilization may affect a firm's decision to bid on a project. If a firm is at or close to capacity, the cost of taking on additional work will be increased. We construct this variable by determining the amount of projects the firm is currently working on (falling between the beginning and ending date) on the day of bidding. For example, Mountain Enterprises bid on a project on November 11, 2007. A search of the awarded contract data indicates that the firm had seven projects under contract on that day. This exercise was replicated for each project for each firm.

Heterogeneity between projects is captured using the state engineer's estimate of the cost of the job. This variable serves as an indicator of the scale of the job. It also lends insight into a firm's business model, i.e. the types of projects they are willing to bid on. In thicker markets some firms target large-scale high-value projects while others concentrate on smaller projects. In thinner markets firms tend to bid on all jobs put out for bid by the KYTC.

A second category of variables captures competitive and strategic effects. We create a variable which counts the number of other competitors whose 60-mile service areas contain the specific project.

This variable measures the number of potential competitors the firm faces when bidding on a project. Another variable measures the number of rival firms that purchased bid proposals for the project. We include this variable to see if knowledge that other firms have expressed an interest in bidding on the project reduces or increases the probability of bidding. This variable captures a strategic element of bidding that may result when firms have some foreknowledge of who will participate in the auction.

Initially a probit model was used following the work of De Silva, Jeitschko, and Kosmopoulou (2009). Problems with that approach arise, however, because there are a number of firms that tend to bid only in their specific counties. The probits we ran with fixed effects of counties are subject to two problems, both of which potentially bias the results in important ways. First, the fixed effects are estimated on small samples, and they cannot be differenced out in a non-linear model like probit. The fact that fixed effects are inconsistent creates bias for the whole model. The inconsistency arises from the lack of variance going to zero, as the county sample does not grow. Second, perfect classification, where a firm either always or never bids in a county, eliminates the county variables and the software drops these variables out of the model. Some firms are affected a lot by this, others very little.[38] This creates in effect a selection bias because firms are not bidding in some counties, which then drop out of the sample rather than staying in with some sort of coefficient. Neither of these problems can be eliminated if probit, logit, or any other non-linear model is used. They constitute unfortunate but unavoidable problems in combining limited dependent variables and fixed effects.

Linear probability models provide a possible alternative, because they provide a linear approximation to whatever underlying model is present and allow the fixed effects to stay in the model regardless of the pattern of bidding. While the linear probability model is controversial because of its range (fitted values outside 0, 1), there is a tradeoff between this problem and the ones discussed in the previous paragraph. Theoretically, the fixed effects in a probit model apply to the propensity score. If the firm does not bid at all in a county the propensity score, which is abstract and unobserved, is negative infinity. That makes no sense—surely there is some nonzero probability of bidding—but the probit model requires this result. The linear probability model only calculates that the probability of bidding is low, which is more realistic. For this reason we present results using linear probability models to estimate the bidding function for each firm.[39]

The sample for each firm includes any project within the firm's 60 mile service area. The dependent variable (y = 1 if the firm bids, y = 0 otherwise) is whether the firm bids on a specific project. The first independent variable consists of 10-mile categorical dummy variables for distance (*Distance)*.[40] The reference category is the distance ring 0 to 10 miles. Breaking distance into 10-mile increments allows us to see where firms are less likely to bid based on distance and the range of each firm's bidding. The next variable is *Jobs Under Contract*, which controls for the number of projects a firm has currently under contract from the KYTC when they bid on a project. The *Engineer's Estimate* is included to control for costs and size of the projects and other heterogeneity associated with each project. *Potential Competitors* indicates how many other firms have the project within their 60 mile service area and could feasibly bid on the project as well.[41] The *Bid Proposal* variable consists of a set of categorical dummy

---

[38] See Appendix A-3 for probit model results for 11 firms. Note that some firms lose a significant number of observations and other firms lose none.

[39] J.S. Butler and Chris Bollinger added invaluable insights into reasons why the linear probability model is the preferred approach for this analysis.

[40] We also estimated bid functions using distance and distance squared. These results were similar to the results with the categorical variables.

[41] We tried several possible alternative specifications of service territories for firms and for their potential competitors, but did not see any major differences in the results.

variables indicating how many other firms have purchased bid proposals.[42] The reference category is when no competitor firms have purchased a bid proposal. Equation (A) expresses this first specification of the bid function:

(A)

$$y = \beta_0 + \beta_1(\text{Distance}) + \beta_2(\text{Jobs Under Contract}) + \beta_3(\text{Engineer's Estimate}) + \\ + \beta_4(\text{Potential Competitors}) + \beta_5(\text{Bid Proposals}) + \varepsilon$$

Distance, the number of jobs under contract, and the engineer's estimate are used to control for cost of the project, which affects whether a firm bids on a project. Distance from the firm to the project is expected to negatively affect the probability of bidding. De Silva, Jeitschko, and Kosmopoulou (2009) find a significant negative relationship between distance and the probability of bidding. KYTC officials have also emphasized the importance of distance in bidding decisions. Previous researchers (e.g. Jofre-Bonet and Pesendorfer (2003), De Silva, Jeitschko, and Kosmopoulou (2009)) have found that the current level of contracted projects (capacity constraints) decreases the probability of bidding. In an interview, KYTC officials expressed that they do not see capacity constraints as an issue, since they schedule projects specifically not to create capacity problems for likely bidders. If capacity constraints do matter then this variable will be negative and significant. As other researchers (e.g. Hong and Shum, 2002) have done, we include the state engineer's estimate of the cost of the project to control for contract heterogeneity as well as the size and scope of the project. Variables for potential competitors and the number of bid proposals purchased by competitors control for the strategic and competitive environment of the bidding. If firms seek to avoid bidding against actual and potential rivals, then it should be captured by these variables.

In a market environment with geographically dispersed asphalt firms and geographically dispersed paving projects, and with no political boundaries defining the location of projects and firms, we would expect the cost variables, especially distance, to be significant determinants of bidding behavior. We would expect the competitive/strategic variables to play a bigger role in thinner markets than in thicker markets. In such an environment with no obvious focal point, it would be difficult for firms to coordinate their bidding.

In a market environment where firms and projects are defined by their location inside or outside certain political boundaries, such as county lines in Kentucky, firms may be able to coordinate their bidding, especially when only a few are involved. In that case location relative to political boundaries would take on greater importance in predicting bidding behavior, and actual distance from plant to project may take on lesser importance. To allow for the importance of these political boundary-location effects, we expand the specification of the bid function as follows:

(B)

$$y = \beta_0 + \beta_1(\text{Distance}) + \beta_2(\text{Jobs Under Contract}) + \beta_3(\text{Engineer's Estimate}) + \\ + \beta_4(\text{Potential Competitors}) + \beta_5(\text{Bid Proposals}) + \beta_6(\text{County : All}) + \varepsilon$$

The *County: All* variable is a set of dummy variables that captures the four scenarios depicted in Figures 2-5. *Project in same county-no rival* (depicted in Figure 2) is the reference category and is

[42] In order to bid on a project a firm must purchase an official bid proposal. These bid proposals cost $10 and the list of firms having purchased bid proposals and hence being eligible to bid on a particular project is published the Friday before the actual bidding takes place. Before 2008, firms could refuse to have their name published on the bid proposal list. It became mandatory for firms to have their names on the list during 2008.

excluded from the regression. This variable indicates that a project is located in a county where the firm has an asphalt plant, and where no rival firms have an asphalt plant. For some firms *Project in same county-rival* (depicted in Figure 4) is used as the reference category, since some firms only have asphalt plants in counties where rival firms also have asphalt plants. *Project in adjacent county-rival* (Figure 3) indicates a project that is in an adjacent county, and a rival firm has an asphalt plant in the county. *Project in adjacent county-no rival* (Figure 5) indicates that a project is in an adjacent county that does not have an asphalt plant in the county.

If in a thin market firms are able to use county boundaries to coordinate bids, these variables will allow us to identify such behavior. If firms X and Y in Counties A and C in Figure 2 are able to solve the coordination game depicted earlier by only bidding within their own county and thereby achieve the dominant Nash equilibrium, then the *Project in adjacent county-rival* variable will be negative and significant, all else constant. This result would mean that, even after controlling for distance, a firm is less likely to bid on a project simply because it is in a county where a rival has an asphalt plant. This result would therefore support a conclusion that firms are tacitly colluding in bidding and "respecting" one another's turf.

Before actually estimating the two above bid functions, it is instructive to look at an example of actual bidding. Figure 7 illustrates the bidding behavior of four central Kentucky asphalt contractors. The major urban center, Lexington, is located in Fayette County, which is surrounded by Scott, Bourbon, Clark, and Madison Counties. ATS Construction has two asphalt plants in Fayette County, which are indicated in the lower left panel of Figure 7. The projects that ATS bid on from 2005 to 2007 are indicated by small red dots, and projects within its service area which it feasibly could have served but did not bid on are indicated by small black circles. With only one exception, ATS bid exclusively on projects located in Fayette County, where its asphalt plants are located. Even though there were dozens and dozens of projects within close proximity to its plants. ATS refrained from bidding on several projects in adjoining counties that were actually closer to its plants than other projects within Fayette County that were farther away.

Nally & Gibson's bidding behavior is illustrated in the upper left panel. Its asphalt plant is located in Scott County, and the projects which it did and did not bid on are indicated by red dots and black circles. Nally & Gibson bid exclusively in Scott County. Hinkle Contracting's bidding behavior is illustrated in the upper right panel. It bid in Bourbon County and in counties north and west of Bourbon County, but never in Scott, Fayette, or Clark counties where the other three companies had asphalt plants. The Allen Company's bidding behavior is illustrated in the lower right panel. Their asphalt plant is located in Madison County, but right on the border with Clark County. The Allen Company bid in both Clark and Madison Counties, but never in Fayette or Bourbon Counties where ATS and Hinkle had plants.

Empirical Results

Now we are ready to discuss the results of the bid function estimations for the 31 firms. There is considerable variation in the estimated bid functions, corresponding to the type of market environment each firm operates in. The entire set of results is voluminous (and available from the authors), but we have selected representative examples to illustrate the different situations.

Competitive Markets

The northern Kentucky geographic market (designated District 6 by KYTC) consists of three densely populated urban/suburban counties (Boone, Kenton, and Campbell) just south of Cincinnati, four suburban/rural counties (Gallatin, Grant, Pendleton, and Bracken) ringing those three counties, and four more rural counties (Carroll, Owen, Harrison, and Robertson) further south. These counties and the location of different firms' asphalt plants are illustrated in Figure 8. Five firms have a total of 13 plants in these 11 counties, with 11 of the plants being located in the more populated areas closest to

Cincinnati. The bids submitted in each of the 11 counties are broken down into multi-bid and single-bid projects in Table 3. Out of 112 projects, 84 (75%) attracted more than one bid. As can be seen, the multi-bid projects attracted on average a low bid that was 15.83 percent below the engineer's estimate, while single bid projects attracted on average a low bid that was 0.06 percent above the engineer's estimate.

Firm-specific plant location and bidding maps are included in Figure 9 for Barrett Paving, Figure 10 for Bluegrass Paving, and Figure 11 for Eaton Asphalt Paving. Table 4 contains the bid function regression results using both specifications (A) and (B) for each of the five firms. Barrett, Bluegrass, and Eaton compete vigorously and bid extensively in Boone, Kenton, and Campbell Counties. Each bids more selectively in Gallatin, Grant, Pendleton, and Bracken Counties. Mago bids extensively in Campbell, Pendleton, Bracken, and Owen Counties close to its plants. Ohio Valley bids primarily in Carroll and Owen Counties close to its plants.

Since Barrett, Bluegrass, and Eaton compete in a fairly dense market in the northernmost region, we analyze their bid functions to see whether econometric estimation supports visual impressions. The Table 4-column (A) results for each of the three firms reveals that distance is a significant predictor of bidding behavior. Barrett and Eaton, with multiple plants, are significantly less likely to bid on projects more than 20 miles from one of their plants. Bluegrass, with only one plant, is less likely to bid on projects more than 10 miles from its plant, with the likelihood of bidding falling even further more than 20 miles out. Bluegrass with its one plant does face capacity issues. The number of jobs under contract does affect the likelihood that it bids on a project. Eaton is less likely to bid on bigger jobs, as measured by the engineer's estimate. Eaton is also less likely to bid if rival firms have purchased bid proposal packets in preparation to bid on a project.

Now we are ready to see whether these three firms coordinate their bids along county boundaries, i.e. tacitly collude, in an effort to suppress competition and raise bid levels. To conduct that test we add county identifiers that indicate own or adjoining county without or with rival asphalt plants. If coordination is occurring we expect these county identifiers to significantly explain observed bidding behavior, perhaps with the distance variables dropping in importance. These regression results are contained in Table 4-Column (B).

The distance variables remain statistically significant and relatively unchanged for all three firms. The county identifiers *Project in adjacent county-rival* and *Project in adjacent county-no rival* are significant for both Barrett and Eaton. For Barrett, these two variables appear to capture Barrett's reluctance to bid in Pendleton County, where Mago has three plants, Harrison County, where only Hinkle Contracting bids, Scott County, where only Nally & Gibson bids, and Owen County, where Eaton, Mago, and Ohio Valley all bid. For Eaton, visual inspection of Figure 11 does not reveal any pattern that would explain the statistical significance of these two variables. Eaton appears to bid without regard to county lines.

The importance of these results is that distance from plant seems to be the primary determinant of bidding for firms in the thick and competitive northern Kentucky market. The addition of county identifiers does not change this fundamental relationship. Fifty-eight out of fifty-nine of the projects put up for bid in Boone, Campbell, Grant, and Kenton Counties from 2005 to 2007 attracted multiple bidders, and averaged 14-17 percent below the engineer's estimate. This is a highly competitive market with no evidence of bid coordination among the market participants.

Duopoly/Oligopoly

Nally & Haydon operates three asphalt plants and bids in four counties in central Kentucky, Washington, Marion, Taylor, and Green. The location of these plants and counties can be seen in Figure 12, which also illustrates asphalt plants belonging to other firms in the surrounding counties. Figure 13 illustrates Nally & Haydon's bidding behavior. As can be seen, Nally & Haydon bids exclusively in these four counties. Inspection of the bidding maps of surrounding paving companies reveals that no other firms bid in any of the four counties in the 2005 to 2007 period.

Table 5 contains the results of estimating Nally & Haydon's bid function. Specification (A) indicates that distance is a significant predictor of bidding. Capacity constraints and potential competitors also are statistically significant. When county indicators are added to the regression, distance becomes less important. The variables *Project in adjacent county-no rival* and *Project in adjacent county-rival* are both negative and significant. The former result bears closer scrutiny. Nally & Haydon bids in Taylor County and doesn't bid in Metcalfe County and Larue County, none of which have asphalt plants. When specific county variables are substituted for *Project in adjacent county-no rival* in the regression, the fit is perfect on *Project in adjacent county-rival* and the county dummies for Taylor, Metcalfe, and Larue Counties.

Natural Monopoly

Discussion of Mountain Enterprises in eastern Kentucky. Tables 6 and 7 and Figures 14 and 15.

Price Wars and Retaliation

Discussion of Scotty's Contracting and Glass Paving interaction in 2006 in Hart, Edmonson, Metcalfe, and Monroe counties.

Maverick Firms

Discussion of H&G Construction in western Kentucky and its impact on Jim Smith Paving's ability to raise prices. Discussion of Kay and Kay's entry into southeastern KY auctions and its impact on Elmo Greer & Sons' bidding behavior.

Financial Impact of Single-Bid Contracts

Tacit collusion in the form of refraining from bidding in KY during the 2005-2007 period resulted in bids that were $70.6 million higher than they would have been if such behavior had not occurred.

Summary and Conclusions

One possible change that could enhance competition in highway procurement auctions would be to remove the focal point that facilitates collusion, namely, do not delineate projects by county lines. The state could go one step further and structure projects so that they are within the potential service territories of multiple asphalt plants.

References

AASHTO. 2006. "Aashto / Fhwa Survey on Construction Cost Increases and Competition," http://www.fhwa.dot.gov/programadmin/contracts/priccomp.cfm.

AASHTO; National Research Council (U.S.). Transportation Research Board.; United States. Army. Corps of Engineers. and United States. Federal Aviation Administration. 2000. *Hot-Mix Asphalt Paving Handbook 2000*. Washington, D.C.: US Army Corps of Engineers.

Anderson, S. D.; Byron C. Blaschke; National Cooperative Highway Research Program.; American Association of State Highway and Transportation Officials. and National Research Council (U.S.). Transportation Research Board. 2004. *Statewide Highway Letting Program Management*. Washington, D.C.: Transportation Research Board.

Andreoni, James and John H. Miller. 1993. "Rational Cooperation in the Finitely Repeated Prisoner's Dilemma: Experimental Evidence." *The Economic Journal*, 103(418), 570-85.

Antitrust Division, Department of Justice. "Price Fixing, Bid Rigging, and Market Allocation Schemes: What They Are and What to Look For," http://www.justice.gov/atr/public/guidelines/211578.htm.

Antitrust Division, Department of Justice http://www.justice.gov/atr/about/antitrust-laws.html.

Asphalt Institute. 2000. *Construction of Hot Mix Asphalt Pavements*. Lexington, KY: Asphalt Institute.

Axelrod, Robert M. 1984. *The Evolution of Cooperation*. New York: Basic Books.

Bajari, Patrick and Gregory Lewis. 2009. "Procurement Contracting with Time Incentives: Theory and Evidence." *National Bureau of Economic Research Working Paper Series*, Working Paper 14855.

Bajari, Patrick and Lixin Ye. 2003. "Deciding between Competition and Collusion." *The Review of Economics and Statistics*, 85(4), 971-89.

Besanko, David. 2010. *Economics of Strategy*. Hoboken, NJ: John Wiley & Sons.

Bureau of Labor Statistics. 2006. "Consumer Price Index - All Urban Consumers," data.bls.gov.

Construction Procurement, Kentucky Transportation Cabinet http://transportation.ky.gov/contract.

Council, South Carolina Legislative Audit. 2001. "A Review of Competition for the Department of Transportation's Road Paving Contracts," D. o. Transportation,

De Silva, Dakshina G; Timothy Dunne; Anuruddha Kankanamge and Georgia. Kosmopoulou. 2008. "The Impact of Public Information on Bidding in Highway Procurement Auctions." *European Economic Review*, 52(1), 150-81.

De Silva, Dakshina G; Timothy Dunne and Georgia Kosmopoulou. 2003. "An Empirical Analysis of Entrant and Incumbent Bidding in Road Construction Auctions." *The Journal of Industrial Economics*, 51(3), 295-316.

De Silva, Dakshina G; Thomas D Jeitschko and Georgia Kosmopoulou. 2009. "Entry and Bidding in Common and Private Value Auctions with an Unknown Number of Rivals." *Review of Industrial Organization*, 35(1-2), 73-93.

De Silva, Dakshina G; Thomas D Jeitschko and Georgia Kosmopoulou. 2005. "Stochastic Synergies in Sequential Auctions." *International Journal of Industrial Organization*, 23(3-4), 183-201.

De Silva, Dakshina G; Georgia Kosmopoulou and Carlos Lamarche. 2009. "The Effect of Information on the Bidding and Survival of Entrants in Procurement Auctions." *Journal of Public Economics*, 93(1-2), 56-72.

Dixit, Avinash K. and Barry Nalebuff. 1991. *Thinking Strategically : The Competitive Edge in Business, Politics, and Everyday Life*. New York: Norton.

Fabra, Natalia. 2003. "Tacit Collusion in Repeated Auctions: Uniform Versus Discriminatory." *The Journal of Industrial Economics*, 51(3), 271-93.

Federal Highway Administration. 1988. "Memorandum: Bid Analysis and Unbalanced Bids," FHWA, August 19, 2010, http://www.fhwa.dot.gov/programadmin/contracts/051688.cfm.

Federal Highway Administration. 2010. "The National Highway System," FHWA, http://www.fhwa.dot.gov/planning/nhs/.

Feinstein, Jonathan S.; Michael K. Block and Frederick C. Nold. 1985. "Asymmetric Information and Collusive Behavior in Auction Markets." *The American Economic Review*, 75(3), 441-60.

Fraas, Arthur G. and Douglas F. Greer, “Market Structure and Price Collusion: An Empirical Analysis,” *Journal of Industrial Economics*, September 1977, 21-44.

Gan, Li and Manuel A. Hernandez. 2011. "Making Friends with Your Neighbors? Agglomeration and Tacit Collusion in the Lodging Industry." *National Bureau of Economic Research Working Paper Series*, No. 16739.

Griffith, Ryan. 2010. "Personal Interview," Frankfort, KY:

Hendricks, Ken; Robert Porter and Guofu Tan. 2008. "Bidding Rings and the Winner's Curse." *The RAND Journal of Economics*, 39(4), 1018-41.

Henriques, Diana B. and Dean Baquet. 1993. "Evidence Mounts of Rigged Bidding in Milk Industry," *The New York Times.*

Hershey, Robert D. Jr. 1988. "Tougher Antitrust Stance Expected," *The New York Times.* New York, NY: 1, March 10, 2010, Hong, Han and Matthew Shum. 2002. "Increasing Competition and the Winner's Curse: Evidence from Procurement." *The Review of Economic Studies*, 69(4), 871-98.

Humrickhouse, Scott and Carol. Edwards. 1997. "Hot-Mix Asphalt Producers Monitor Profitability through Benchmarking," *Roads & Bridges.* Arlington Heights Illinois: Scranton Gillette Communications Inc.,

Jofre-Bonet, Mireia and Martin Pesendorfer. 2003. "Estimation of a Dynamic Auction Game." *Econometrica*, 71(5), 1443-89.

Kentucky Transportation Cabinet. 2010a. "2010 Recommended Highway Plan," K. T. Cabinet, Frankfort: Kentucky Transportation Cabinet, http://transportation.ky.gov/highways/.

Kentucky Transportation Cabinet. 2005. "Contract Procurement," Division of Contract Procurement, Frankfort: Kentucky Transportation Cabinet,, August 19, 2010, http://transportation.ky.gov/kytci-forms/PolicyManuals.htm.

Kentucky Transportation Cabinet. 2006a. *Highway Design Guidance Manual*. Frankfort, Kentucky: Kentucky Transportation Cabinet.

Kentucky Transportation Cabinet. 2007. "Interested Parties, Public Involvement & Consultation Process," Division of Program Management, Frankfort: Kentucky Transportation Cabinet, August 16, 2010, http://transportation.ky.gov/progmgmt/.

Kentucky Transportation Cabinet. 2006b. "Kentucky Long-Range Statewide Transportation Plan," Division of Planning, Frankfort: Kentucky Transportation Cabinet, 66, http://transportation.ky.gov/planning/stp/2006stp.asp.

Kentucky Transportation Cabinet. 2010b. "List of Approved Materials," Division of Materials, Frankfort, KY: Kentucky Transportation Cabinet,, May 25, 2010, http://transportation.ky.gov/materials/.

Kentucky Transportation Cabinet. 2004. "Statewide Transportation Improvement Plan for Fy 2005-2007," Division of Program Management, Frankfort: Kentucky Transportation Cabinet, August 16, 2010, http://transportation.ky.gov/progmgmt/stip/stip1.htm.

Kentucky Transportation Cabinet, Division of Planning. . "Kentucky Transportation Cabinet Highway Districts," http://www.planning.kytc.ky.gov/maps/boundaries/boundaries.asp.

Klemperer, P. D., *Auctions: Theory and Practice*, Princeton: Princeton University Press, 2004.

Knittel, Christopher R. and Victor Stango. 2003. "Price Ceilings as Focal Points for Tacit Collusion: Evidence from Credit Cards." *The American Economic Review*, 93(5), 1703-29.

Krasnokutskaya, Elena. 2011. "Identification and Estimation of Auction Models with Unobserved Heterogeneity." *The Review of Economic Studies*, 78(1), 293-327.

Krasnokutskaya, Elena and Katja Seim. 2010. "Bid Preference Programs and Participation in Highway Procurement." *The American Economic Review*, Forthcoming.

Kreps, David M. Kreps; Paul Milgrom; John Roberts and Robert Wilson. 1982. "Rational Cooperation in the Finitely Repeated Prisoners' Dilemma." *Journal of Economic Theory*, (27), 242-52.

Lanzillotti, Robert. 1996. "The Great Milk Conspiracies of the 1980s." *Review of Industrial Organization*, 2(August), 413-58.

Li, Tong and Xiaoyong Zheng. 2009. "Entry and Competition Effects in First-Price Auctions: Theory and Evidence from Procurement Auctions." *The Review of Economic Studies*, 76(4), 1397-429.

Marion, Justin. 2007. "Are Bid Preferences Benign? The Effect of Small Business Subsidies in Highway Procurement Auctions." *Journal of Public Economics*, 91(7-8), 1591-624.

McAfee, R. Preston and John McMillan. 1992. "Bidding Rings." *The American Economic Review*, 82(3), 579-99.

PAIKY. 2010. "Where Liquid Asphalt Comes From," A short description of the process used to get liquid asphalt from crude oil., www.paiky.org.

Pasztor, Andy. 1985. "Busting a Trust: Electrical Contractors Reel under Charges That They Rigged Bids---How Anonymous Letter Led to Flurry of Prosecutions; 'Super Conspiracy' Theory --- Code Words and Kickbacks," *The Wall Street Journal.* 1,

Pesendorfer, Martin. 2000. "A Study of Collusion in First-Price Auctions." *The Review of Economic Studies*, 67(3), 381-411.

Porter, Robert H., "Detecting Collusion," *Review of Industrial Organization*, March 2005, 147-167.

Porter, Robert H. and J. Douglas Zona. 1993. "Detection of Bid Rigging in Procurement Auctions." *The Journal of Political Economy*, 101(3), 518-38.

Porter, Robert H. and J. Douglas Zona. 1999. "Ohio School Milk Markets: An Analysis of Bidding." *The RAND Journal of Economics*, 30(2), 263-88.

Press, Robert M. 1982. "Blowing the Whistle on Bid Rigging," *Christian Science Monitor.* March 10, 2010,

Price, Michael K. 2008. "Using the Spatial Distribution of Bidders to Detect Collusion in the Marketplace: Evidence from Timber Auctions." *Journal of Regional Science*, 48(2), 399-417.

Rosewicz, Barbara. 1984. "New Antitrust Chief Says He's as Tough as Predecessor," *United Press International.* March 10, 2010,

Ryan, Sean. 2004. "Wisdot Seminar Draws 270," *The Daily Reporter* Milwaukee, WI: March 10, 2010, Scott, Frank A. . 2000. "Great School Milk Conspiracies Revisited." *Review of Industrial Organization*, 17(November), 325-41.

Smith, Adam, *The Wealth of Nations*, Chicago: University of Chicago Press, 1976 edition.

Smith, Diane. 1988. "Lawsuit Charges Major Milk Producers Fixed Prices of Kids' Milk," *The Associated Press.* March 10, 2010,

Sniffen, Michael J. 1984. "Federal Highway Bid-Rigging Probe Expands into 29th State," *The Associated Press.* March 10, 2010,

Sniffen, Michael J. 1982. "Highway Bid-Rigging Investigation Expanded to Five New States," *The Associated Press.* March 10, 2010,

Stigler, George, "The Economic Effects of the Antitrust Laws," *Journal of Law and Economics*, October 1966, as reprinted in *The Organization of Industry*, Chicago: University of Chicago Press, 1968.

The Associated Press. 2004. "Asphalt Makers Studied: Epa Action Now Includes 5 States, but Reason Not Apparent " *Cincinnati Enquirer.* Cincinnati, OH: http://www.enquirer.com/editions/2004/07/06/loc_loc1ohasph.html.

U.S. General Accounting Office, *Changes in Antitrust Enforcement Policies and Activities*, GAO/GGD-91-2, October 1990.

Werden, Gregory J. 2004. "Economic Evidence on the Existence of Collusion: Reconciling Antitrust Law with Oligopoly Theory." *Antitrust Law Journal* 71, 719-800.

Yao, Dennis A. and Susan S. DeSanti. 1993. "Game Theory and the Legal Analysis of Tacit Collusion." *The Antitrust Bulletin*, 38(113).

Table 1: Summary Statistics of all projects in Kentucky – 2005 to 2007

	Number of Projects		Total Value of Projects ($ in millions)		Over or Under Engineer's Estimate (%)	
Number of Bidders	Asphalt Paving	All Other Projects*	Asphalt Paving	All Other Projects*	Asphalt Paving	All Other Projects*
1	680	154	437.8	737.6	2.22	2.38
2	287	223	121.8	800.8	-13.53	-6.02
3	76	211	36.0	488.3	-16.73	-13.22
4	29	153	11.4	174.4	-15.35	-16.02
5	3	83	1.8	144.0	-14.15	-19.52
6		43		49.8		-17.22
7		23		44.0		-21.30
8		12		17.1		-16.07
9		7		4.6		-26.08
12		1		0.7		-11.05
Grand Total	**1075**	**910**	**608.8**	**2,461.1**	**-3.84**	**-10.39**

*These other projects include grade and drain, bridge, mowing, concrete, etc. Some of these projects have asphalt components as part of the project.

Table 2: Firm bidding and the value of winning contracts

		Asphalt Paving Projects Bid on		Asphalt Paving Contracts Won	
Firms	Number of Plants	Number of Bids	Firm only bidder on project (%)	Number of Projects Won	Contracted Value of Winning Projects ($)
THE ALLEN COMPANY INC	3	54	50	49	15,308,473.15
ATS CONSTRUCTION	2	21	100	21	39,934,777.30
BARRETT PAVING MATERIALS INC	3	63	0	16	4,376,192.58
BLACKTOP INDUSTRIES & EQUIPMENT COMPANY	1	11	0	2	528,974.50
BLUEGRASS PAVING	1	31	0	8	2,227,065.31
COMMERCIAL PAVERS INC	3	53	0	24	18,353,377.60
EATON ASPHALT PAVING CO INC	5	99	3	43	12,210,883.50
ELMO GREER & SONS LLC	10	69	55	66	34,306,098.30
FLYNN BROTHERS CONTRACTING INC	2	31	0	6	2,987,221.00
GADDIE-SHAMROCK LLC	3	29	79	28	26,117,688.71
GLASS PAVING INC	2	20	70	16	10,558,645.85
H & G CONSTRUCTION COMPANY INC	1	77	0	14	6,106,025.76
H G MAYS CORPORATION	3	38	45	32	16,388,222.00
HINKLE CONTRACTING CORPORATION	11	107	92	103	51,571,836.47
JIM SMITH CONTRACTING COMPANY LLC	3	86	14	71	28,711,260.19
KAY & KAY CONTRACTING LLC	1	33	0	3	719,879.00
LEXINGTON QUARRY COMPANY	1	17	76	14	7,117,499.10
LINCOLN COUNTY READY MIX INC	1	28	0	5	2,226,384.48
MAGO CONSTRUCTION COMPANY LLC	12	102	46	88	38,670,973.43
MOUNTAIN ENTERPRISES INC	13	150	87	144	77,543,544.78
MURRAY PAVING	1	4	25	4	1,765,535.60
NALLY & GIBSON GEORGETOWN LLC D/B/A	1	11	100	11	4,804,703.60
NALLY & HAYDON SURFACING LLC	3	30	97	30	12,967,285.12
OHIO VALLEY ASPHALT LLC	3	33	39	27	7,344,865.32
QUALIFIED PAVING LLC	1	17	0	10	7,281,674.44
ROAD BUILDERS & PARKWAY CONSTRUCTION LLC	2	38	76	33	24,192,496.38
ROGERS GROUP INC	5	55	71	50	37,252,115.20
SCOTTY'S CONTRACTING AND STONE LLC	12	119	61	96	69,271,902.25
SHELBYVILLE ASPHALT COMPANY LLC	1	6	17	3	692,378.10
THE WALKER COMPANY OF KENTUCKY INC	2	22	86	21	7,110,045.55
YAGER MATERIALS LLC	1	28	68	21	24,133,747.90

Table 3*:* **Summary of Bidding for Counties in Northern Kentucky (District 6)**

	Multi-bid projects			Single-bid projects			Tacit Collusion		
COUNTY	Number of Projects	Contracted Value of Projects	% Value Over/Under Engineer's Estimate	Number of Projects	Contracted Value of Projects	% Value Over/Under Engineer's Estimate	Evidence? (Yes or No)	Firms Involved	Financial Impact
WITHOUT ASPHALT PLANTS									
Harrison				7	$ 2,581,285.95	3.73	Yes	Eight Firms (A)	**$ 504,899.53**
Owen	6	$ 1,767,717.10	-13.48	1	$ 629,368.90	2.89	Yes	Eight Firms (B)	**$ 117,817.86**
Robertson	4	$ 475,851.38	-19.68	1	$ 263,149.60	-5.53	Yes	Eight Firms (C)	**$ 27,104.41**
TOTAL (WITHOUT ASPHALT PLANTS)	**10**	**$ 2,243,568.48**	**-15.96**	**9**	**$ 3,473,804.45**	**2.61**			
WITH ASPHALT PLANTS									
Boone	17	$ 4,436,877.11	-16.27				Yes	Four Firms (D)	Competitive
Bracken	6	$ 976,928.23	-15.28	3	$ 1,415,728.80	-4.08	Yes	Four Firms (E)	**$ 166,348.13**
Campbell	15	$ 3,459,520.00	-17.75				Yes	Two Firms (F)	Competitive
Carroll	1	$ 214,163.00	-13.20	8	$ 1,704,494.90	2.96	Yes	Three Firms (G)	**$ 320,274.59**
Gallatin	4	$ 858,039.21	-12.14	2	$ 305,804.00	-3.64	Yes	Five Firms (H)	**$ 37,277.51**
Grant	9	$ 2,970,340.01	-17.15				Yes	Six Firms (I)	Competitive
Kenton	18	$ 5,562,071.10	-14.74	1	$ 257,550.00	-26.33	Yes	Three Firms (J)	Competitive
Pendleton	4	$ 1,569,399.70	-13.59	5	$ 1,852,404.03	0.08	Yes	Five Firms (I)	**$ 294,717.48**
TOTAL (WITH ASPHALT PLANTS)	**74**	**$ 20,047,338.36**	**-15.81**	**19**	**$ 5,535,981.73**	**-1.15**			
TOTAL (DISTRICT 6)	**84**	**$ 22,290,906.84**	**-15.83**	**28**	**$ 9,009,786.18**	**0.06**			**$845,722.12**

(A) These firms include The Allen Company, ATS Construction, Barrett Paving, Hinkle Contracting, Lexington Quarry, Mago Construction, Nally & Gibson Georgetown, and The Walker Company
(B) These firms include ATS Construction, Barrett Paving, Commercial Pavers, Eaton Asphalt Paving, H.G. Mays, Mago Construction, Nally & Gibson Georgetown, and Ohio Valley Asphalt
(C) These firms include The Allen Company, Barrett Paving, Eaton Asphalt Paving, H.G. Mays, Hinkle Contracting, Mago Construction, Nally & Gibson Georgetown, and The Walker Company
(D) These firms include Barrett Paving, Eaton Asphalt Paving, Mago Construction, and Ohio Valley Asphalt
(E) These firms include Barrett Paving, H.G. Mays, Hinkle Contracting, and Mago Construction
(F) These firms include Barrett Paving and H.G. Mays
(G) These firms include Commercial Pavers, Eaton Asphalt Paving, and Ohio Valley Asphalt
(H) These firms include Eaton Asphalt Paving, H.G. Mays, Mago Construction, Nally & Gibson Georgetown, and Ohio Valley Asphalt.
(I) These firms include ATS Construction, Barrett Paving, H.G. Mays, Hinkle Contracting, Mago Construction, and Nally & Gibson Georgetown
(J) These firms include Eaton Asphalt Paving, Mago Construction, and Ohio Valley Asphalt

Table 4: Regression results for Northern Kentucky (District 6) Firms

	Barrett Paving		Bluegrass Paving		Eaton Asphalt Paving		Mago Construction		Ohio Valley Asphalt	
VARIABLES	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Distance (11 to 20 miles)	-0.00590	0.0156	-0.255*	-0.227*	-0.0491	-0.0666	-0.454***	-0.249***	-0.468***	-0.00301
	(0.0637)	(0.0572)	(0.133)	(0.134)	(0.0808)	(0.0839)	(0.0581)	(0.0635)	(0.105)	(0.0828)
Distance (21 to 30 miles)	-0.591***	-0.379***	-0.544***	-0.428**	-0.245***	-0.185*	-0.727***	-0.425***	-0.606***	-0.0681
	(0.112)	(0.117)	(0.139)	(0.167)	(0.0937)	(0.0972)	(0.0514)	(0.0716)	(0.110)	(0.117)
Distance (31 to 40 miles)	-0.897***	-0.653***	-0.773***	-0.659***	-0.392***	-0.323***	-0.829***	-0.505***	-0.693***	-0.162
	(0.0579)	(0.0904)	(0.114)	(0.144)	(0.101)	(0.106)	(0.0478)	(0.0724)	(0.0985)	(0.103)
Distance (41 to 50 miles)	-0.885***	-0.624***	-0.768***	-0.683***	-0.761***	-0.687***	-0.862***	-0.515***	-0.776***	-0.271***
	(0.0656)	(0.0967)	(0.119)	(0.139)	(0.0750)	(0.0840)	(0.0479)	(0.0742)	(0.0872)	(0.101)
Distance (51 to 60 miles)	-0.884***	-0.608***	-0.746***	-0.651***	-0.778***	-0.707***	-0.889***	-0.545***	-0.811***	-0.294***
	(0.0653)	(0.104)	(0.124)	(0.147)	(0.0717)	(0.0793)	(0.0491)	(0.0763)	(0.0871)	(0.103)
Jobs Under Contract	-0.00269	-0.00561	-0.157***	-0.151**	0.00779	0.00848	0.00350	0.00231	0.000483	0.000756
	(0.0193)	(0.0179)	(0.0582)	(0.0594)	(0.0103)	(0.0102)	(0.00440)	(0.00360)	(0.0113)	(0.0100)
Engineer's Estimate	9.46e-10	1.99e-09	2.10e-07	2.04e-07	-4.82e-08***	-4.49e-08***	-4.65e-10	2.63e-09	-2.42e-08*	-1.23e-08
	(1.48e-09)	(1.82e-09)	(1.38e-07)	(1.33e-07)	(1.78e-08)	(1.63e-08)	(3.30e-09)	(2.38e-09)	(1.29e-08)	(1.09e-08)
Potential Competitors	-0.0149	-0.0169**	0.00292	0.00313	-0.0168**	-0.0172**	-0.0188***	-0.0114***	-0.00961	-0.00653
	(0.0104)	(0.00835)	(0.0130)	(0.0132)	(0.00802)	(0.00816)	(0.00492)	(0.00415)	(0.00584)	(0.00499)
One competitive bid proposal purchased	0.0373	0.0170	0.111	0.115	-0.241***	-0.0253	-0.470***	-0.189***	-0.412***	-0.258**
	(0.0493)	(0.0475)	(0.0781)	(0.0790)	(0.0803)	(0.0457)	(0.0552)	(0.0620)	(0.105)	(0.117)
Two competitive bid proposals purchased	-0.00684	-0.0206	0.188**	0.196**	-0.108	0.102	-0.510***	-0.214***	-0.455***	-0.315***
	(0.0344)	(0.0446)	(0.0769)	(0.0793)	(0.0779)	(0.0686)	(0.0574)	(0.0679)	(0.103)	(0.116)
Three or more competitive bid proposals purchased					-0.282**	-0.0486	-0.632***	-0.273***	-0.601***	-0.436***
					(0.109)	(0.0940)	(0.0572)	(0.0709)	(0.0964)	(0.109)
Project in same county-rival		-0.0460				-0.109*		0.182**		
		(0.0377)				(0.0656)		(0.0715)		
Project in adjacent county-no rival		-0.276***		-0.0974		-0.300***		-0.380***		-0.520***
		(0.0736)		(0.134)		(0.0877)		(0.0842)		(0.105)
Project in adjacent county-rival		-0.380***		-0.173		-0.310***		-0.527***		-0.638***
		(0.104)		(0.146)		(0.0878)		(0.0793)		(0.0949)
Constant	1.044***	1.179***	0.592***	0.640***	1.162***	1.180***	1.488***	1.278***	1.394***	1.294***
	(0.0526)	(0.0644)	(0.133)	(0.166)	(0.102)	(0.108)	(0.0811)	(0.0735)	(0.114)	(0.107)
Observations	182	182	135	135	244	244	570	570	231	231
R-squared	0.803	0.841	0.536	0.547	0.557	0.572	0.577	0.692	0.585	0.665

Robust standard errors in parentheses

Note: The reference cateogry in all specifications is "Project in same county-no rival".

There are some cases w here firms only have plants in counties w here other rivals have their plants.

In this case "Project in same county-rival" is the reference category.

*** p<0.01, ** p<0.05, * p<0.1

Table 5: Regression results for Central Kentucky (District 4) Firms

VARIABLES	Glass Paving (A)	Glass Paving (B)	Mago Construction (A)	Mago Construction (B)	Nally & Haydon Surfacing (A)	Nally & Haydon Surfacing (B)	Qualified Paving (A)	Qualified Paving (B)	Scotty's Contracting and Stone (A)	Scotty's Contracting and Stone (B)
Distance (11 to 20 miles)	-0.0834	0.0106	-0.454***	-0.249***	-0.101	0.0391	-0.372	-0.318	0.0557	0.0795
	(0.171)	(0.0132)	(0.0581)	(0.0635)	(0.0891)	(0.0679)	(0.261)	(0.285)	(0.0687)	(0.0562)
Distance (21 to 30 miles)	-0.502***	0.0706	-0.727***	-0.425***	-0.409***	-0.219*	-0.381*	-0.00350	-0.231***	-0.0201
	(0.184)	(0.0509)	(0.0514)	(0.0716)	(0.143)	(0.114)	(0.215)	(0.310)	(0.0864)	(0.0886)
Distance (31 to 40 miles)	-0.616***	0.0208	-0.829***	-0.505***	-0.457***	-0.265**	-0.667***	-0.284	-0.511***	-0.254***
	(0.175)	(0.0490)	(0.0478)	(0.0724)	(0.144)	(0.116)	(0.168)	(0.282)	(0.0859)	(0.0913)
Distance (41 to 50 miles)	-0.651***	-0.00754	-0.862***	-0.515***	-0.437***	-0.257**	-0.622***	-0.244	-0.577***	-0.299***
	(0.172)	(0.0321)	(0.0479)	(0.0742)	(0.142)	(0.114)	(0.169)	(0.281)	(0.0817)	(0.0878)
Distance (51 to 60 miles)	-0.649***	-0.00692	-0.889***	-0.545***	-0.449***	-0.254**	-0.739***	-0.353	-0.595***	-0.343***
	(0.173)	(0.0292)	(0.0491)	(0.0763)	(0.143)	(0.114)	(0.160)	(0.278)	(0.0804)	(0.0891)
Jobs Under Contract	0.0243**	0.00811	0.00350	0.00231	0.0225**	0.0160*	0.0922***	0.0898***	0.00296	0.00241
	(0.0112)	(0.00664)	(0.00440)	(0.00360)	(0.00950)	(0.00849)	(0.0296)	(0.0296)	(0.00412)	(0.00367)
Engineer's Estimate	6.51e-09	2.46e-09	-4.65e-10	2.63e-09	-1.59e-09	-7.19e-10	-2.21e-09	2.75e-10	-8.54e-09	-8.54e-09
	(5.12e-09)	(2.40e-09)	(3.30e-09)	(2.38e-09)	(2.21e-09)	(1.82e-09)	(6.33e-09)	(6.96e-09)	(1.12e-08)	(7.60e-09)
Potential Competitors	-0.00299	-0.00348	-0.0188***	-0.0114***	-0.00405**	-0.00171	-0.0176	-0.0149	-0.0134***	-0.00315
	(0.00382)	(0.00238)	(0.00492)	(0.00415)	(0.00197)	(0.00141)	(0.0129)	(0.0127)	(0.00506)	(0.00393)
One competitive bid proposal purchased	-0.445***	-0.0170	-0.470***	-0.189***	-0.619***	-0.432***	0.0118	0.00980	-0.419***	-0.238***
	(0.156)	(0.0176)	(0.0552)	(0.0620)	(0.116)	(0.119)	(0.0514)	(0.0508)	(0.0607)	(0.0469)
Two competitive bid proposals purchased	-0.501***	-0.0552	-0.510***	-0.214***	-0.681***	-0.501***	0	0	-0.373***	-0.251***
	(0.157)	(0.0353)	(0.0574)	(0.0679)	(0.108)	(0.112)	(0)	(0)	(0.0744)	(0.0580)
Three or more competitive bid proposals purchased	-0.459***	-0.0215	-0.632***	-0.273***	-0.645***	-0.436***	0.128*	0.105	-0.366***	-0.160***
	(0.155)	(0.0218)	(0.0572)	(0.0709)	(0.113)	(0.119)	(0.0764)	(0.0781)	(0.0670)	(0.0500)
Project in same county-rival		0.0179		0.182**						-0.181*
		(0.0188)		(0.0715)						(0.108)
Project in adjacent county-no rival		-0.933***		-0.380***		-0.288**		-0.330		-0.189***
		(0.0471)		(0.0842)		(0.111)		(0.226)		(0.0625)
Project in adjacent county-rival		-0.955***		-0.527***		-0.371***		-0.401*		-0.544***
		(0.0504)		(0.0793)		(0.110)		(0.234)		(0.0708)
Constant	1.080***	0.990***	1.488***	1.278***	1.091***	1.048***	0.724***	0.712***	1.065***	1.024***
	(0.119)	(0.0204)	(0.0811)	(0.0735)	(0.0657)	(0.0468)	(0.200)	(0.203)	(0.0582)	(0.0426)
Observations	146	146	570	570	291	291	131	131	339	339
R-squared	0.674	0.842	0.577	0.692	0.833	0.862	0.332	0.345	0.652	0.740

Table 6: **Summary of Bidding for Counties in Eastern Kentucky (District 12)**

	Multi-bid projects			Single-bid projects			Tacit Collusion		
COUNTY	Number of Projects	Contracted Value of Projects	% Value Over/Under Engineer's Estimate	Number of Projects	Contracted Value of Projects	% Value Over/Under Engineer's Estimate	Evidence? (Yes or No)	Firms Involved	Financial Impact
WITHOUT ASPHALT PLANTS									
Knott				9	$ 3,140,620.10	5.39	Yes	Two Firms (A)	**$ 617,759.97**
TOTAL (WITHOUT ASPHALT PLANTS)				**9**	**$ 3,140,620.10**	**5.39**			
WITH ASPHALT PLANTS									
Floyd				10	$ 5,875,309.72	4.87	No	One Firm (B)	
Johnson	3	$ 603,329.20	5.98	5	$ 1,714,740.42	4.17	Yes	Two Firms (A)	**$ 316,369.61**
Lawrence	3	$ 877,179.10	-7.53	6	$ 1,842,513.50	7.20	Yes	Two Firms (A)	**$ 395,771.90**
Letcher				14	$ 7,069,779.75	9.47	No	One Firm (B)	
Martin				9	$ 8,943,287.60	2.68	No	-	
Pike				15	$ 9,491,988.40	3.24	No	One Firm (B)	
TOTAL (WITH ASPHALT PLANTS)	**6**	**$ 1,480,508.30**	**-0.78**	**59**	**$34,937,619.39**	**5.39**			
TOTAL (DISTRICT 12)	**6**	**$ 1,480,508.30**	**-0.78**	**68**	**$38,078,239.49**	**5.39**			**$1,329,901.48**

(A) These firms include Hinkle Contracting and Mountain Enterprises

(B) This firm is Mountain Enterprises

Table 7: Regression results for Eastern Kentucky (District 12) Firms

	Mountain Enterprises	
VARIABLES	(A)	(B)
Distance (11 to 20 miles)	0.0358	0.0452
	(0.0363)	(0.0302)
Distance (21 to 30 miles)	-0.0853*	-0.0297
	(0.0444)	(0.0377)
Distance (31 to 40 miles)	-0.336***	-0.221***
	(0.0674)	(0.0566)
Distance (41 to 50 miles)	-0.482***	-0.326***
	(0.0691)	(0.0582)
Distance (51 to 60 miles)	-0.463***	-0.371***
	(0.0688)	(0.0606)
Jobs Under Contract	-0.00698**	-0.00363
	(0.00298)	(0.00244)
Engineer's Estimate	-2.04e-08	-1.35e-08
	(1.51e-08)	(8.92e-09)
Potential Competitors	-0.0150***	-0.0108*
	(0.00528)	(0.00601)
One competitive bid proposal purchased	-0.491***	-0.320***
	(0.0632)	(0.0574)
Two competitive bid proposals purchased	-0.548***	-0.277***
	(0.0752)	(0.0789)
Three or more competitive bid proposals purchased	-0.761***	-0.439***
	(0.137)	(0.113)
Project in same county-rival		0.0151
		(0.0481)
Project in adjacent county-no rival		-0.0994***
		(0.0333)
Project in adjacent county-rival		-0.418***
		(0.0525)
Constant	1.163***	1.108***
	(0.0445)	(0.0373)
Observations	279	279
R-squared	0.828	0.878

Robust standard errors in parentheses

Note: The reference cateogry in all specifications is "Project in same county-no rival".

There are some cases w here firms only have plants in counties w here other rivals have their plants.

In this case "Project in same county-rival" is the reference category.

*** p<0.01, ** p<0.05, * p<0.1

Figure 1: Asphalt Plant Locations in Kentucky

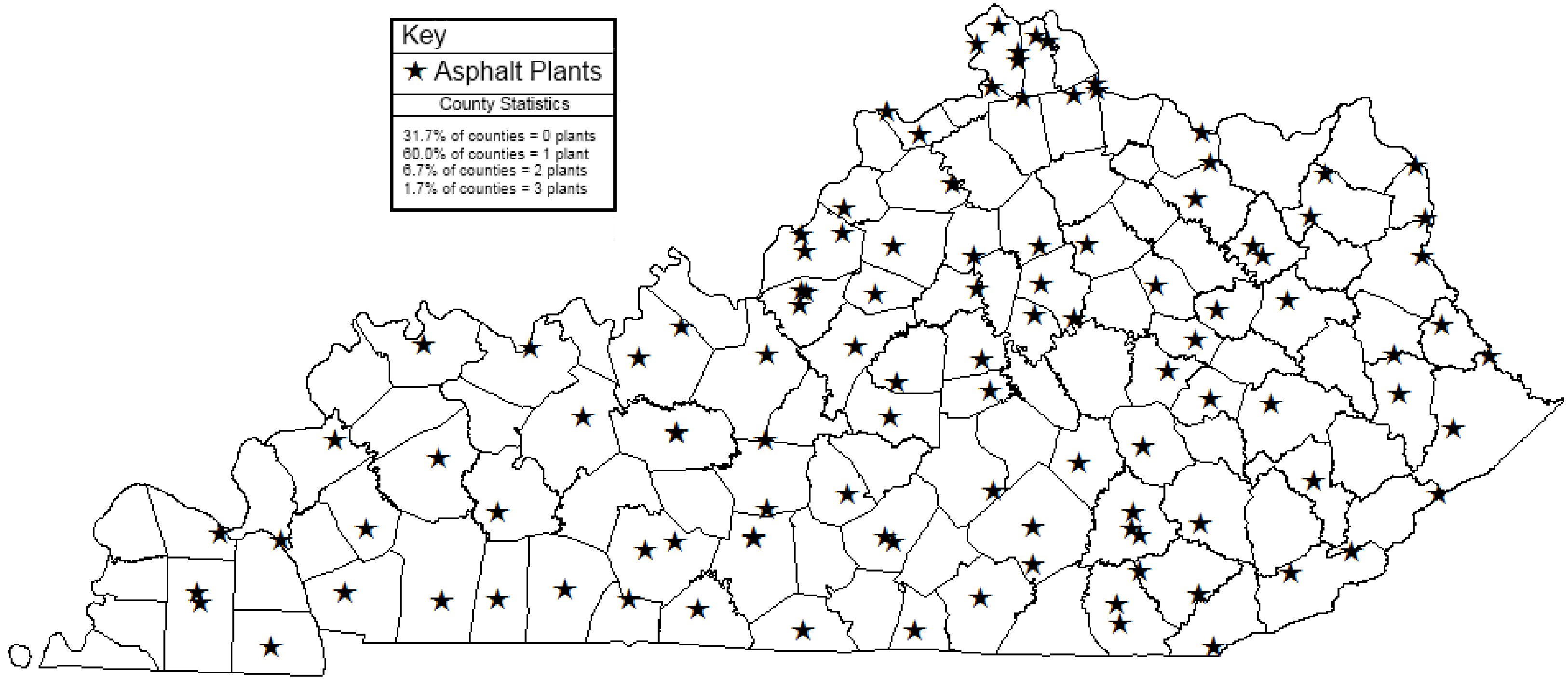


Figure 2: Project in same county without rival

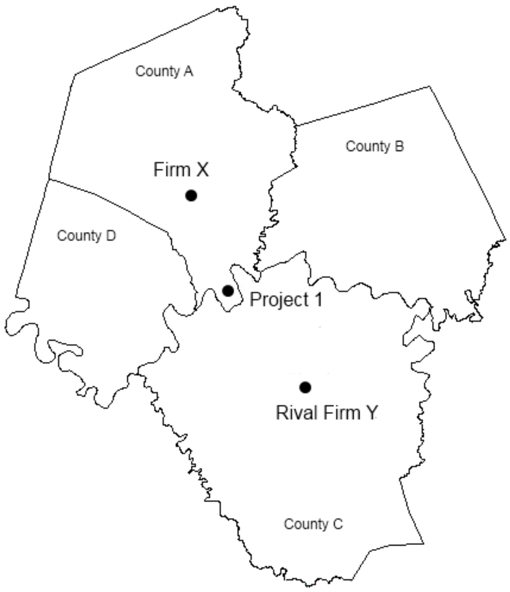


Figure 3: Project in adjacent county with rival asphalt plant

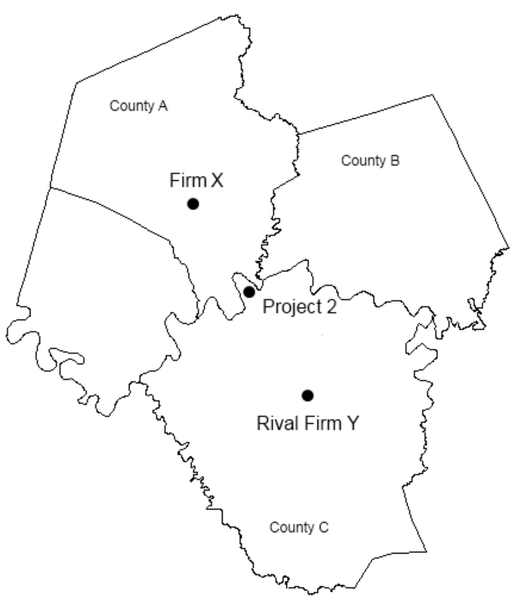


Figure 4: Project in county with two rival asphalt plants

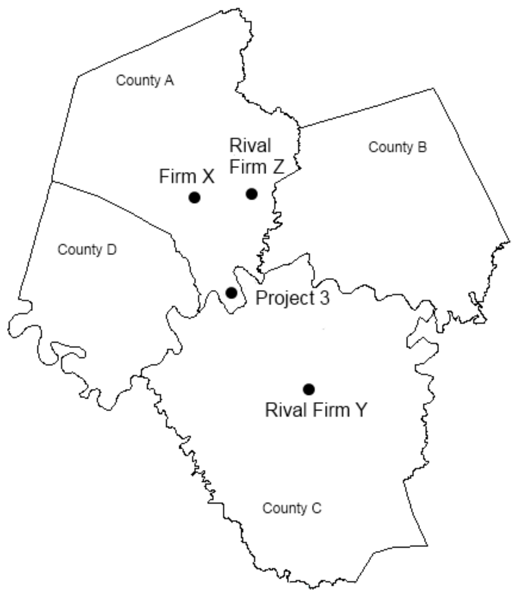


Figure 5: Project in adjacent county with no asphalt plant

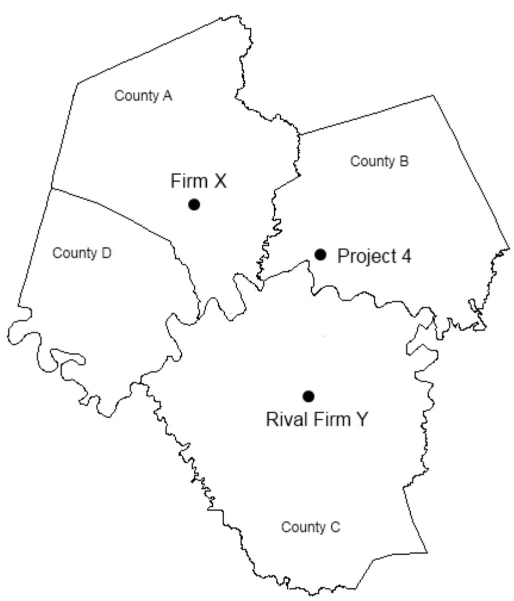


Figure 6: Service area – H&G Construction

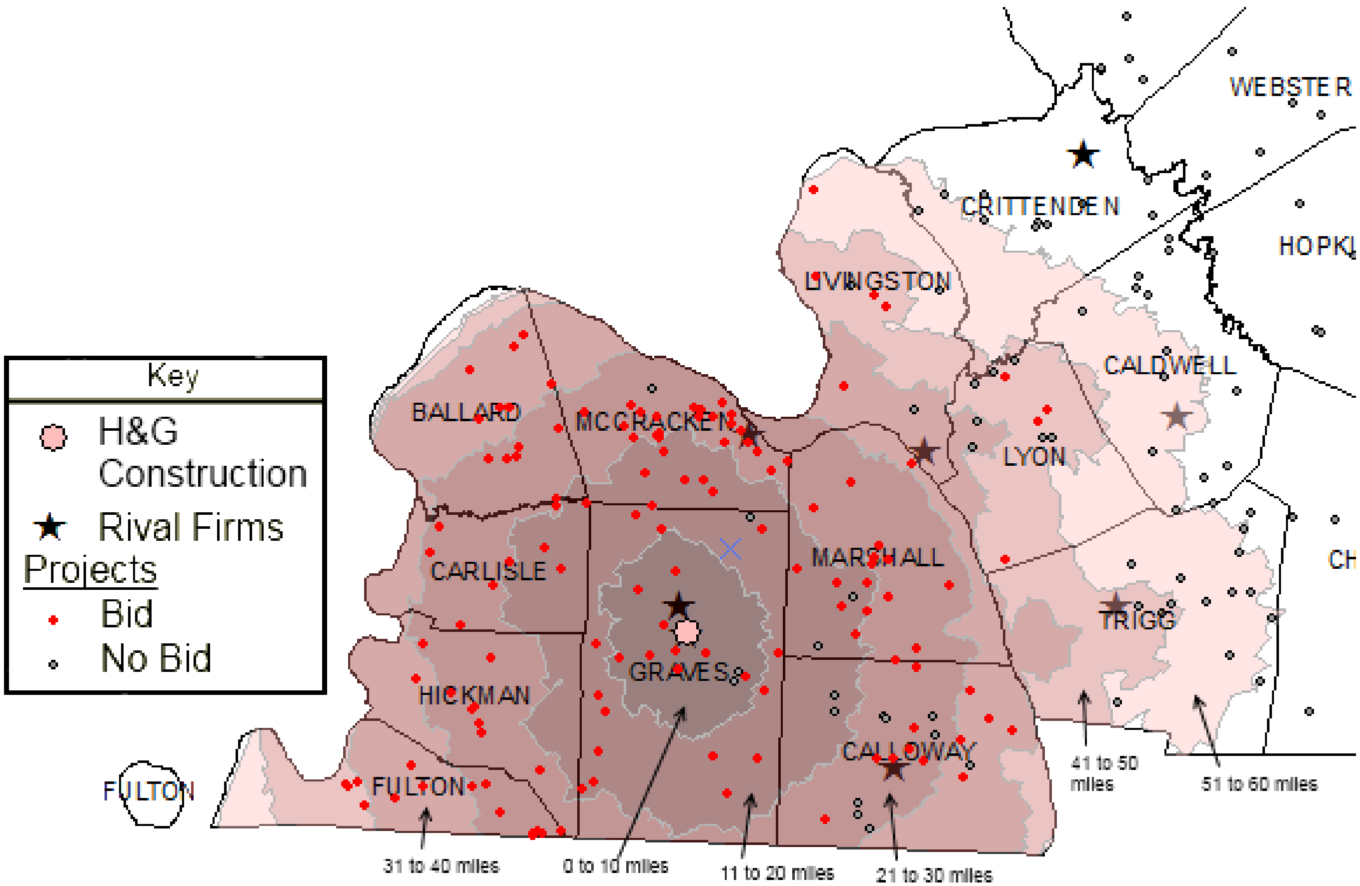


Figure 7: Bidding behavior of four firms in Central Kentucky

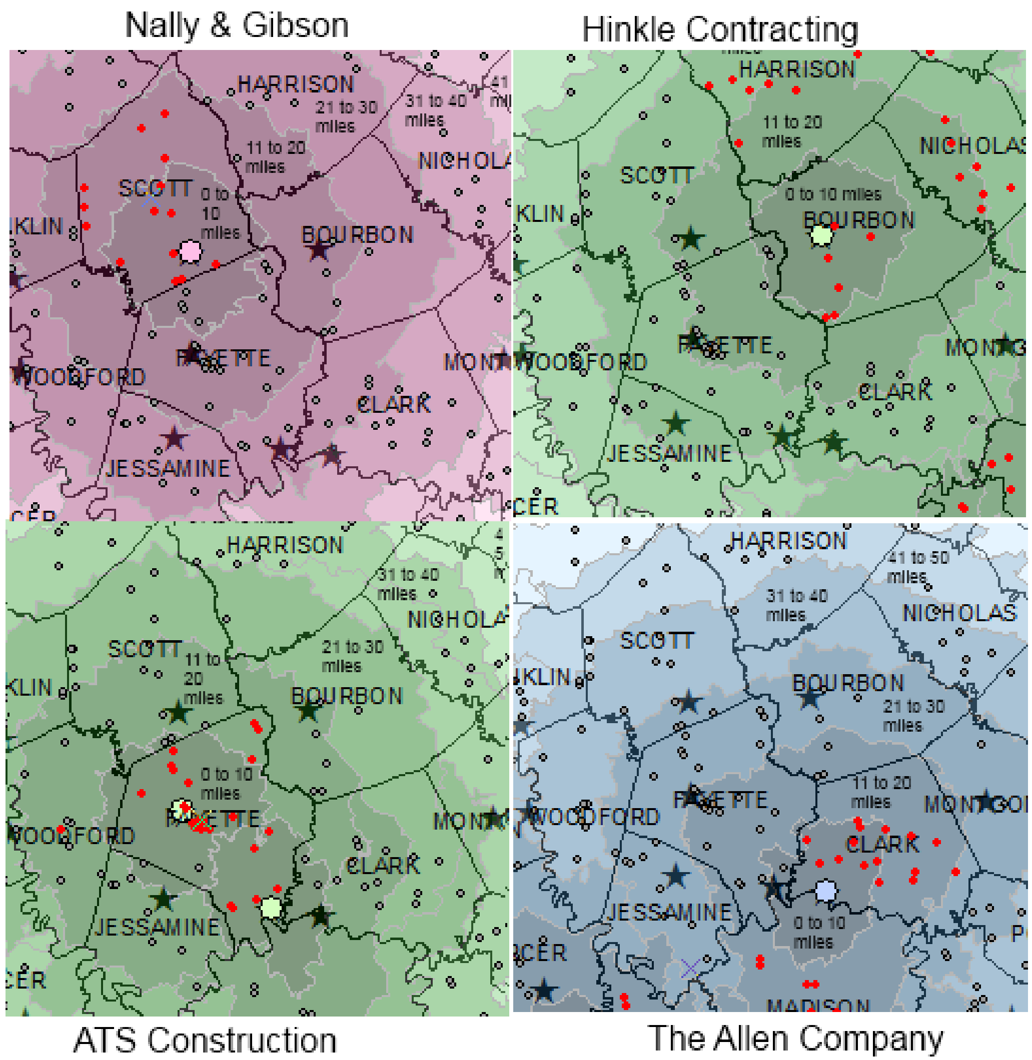


Figure 8: Northern Kentucky (KYTC District 6) Counties, Firms, and Asphalt Plants

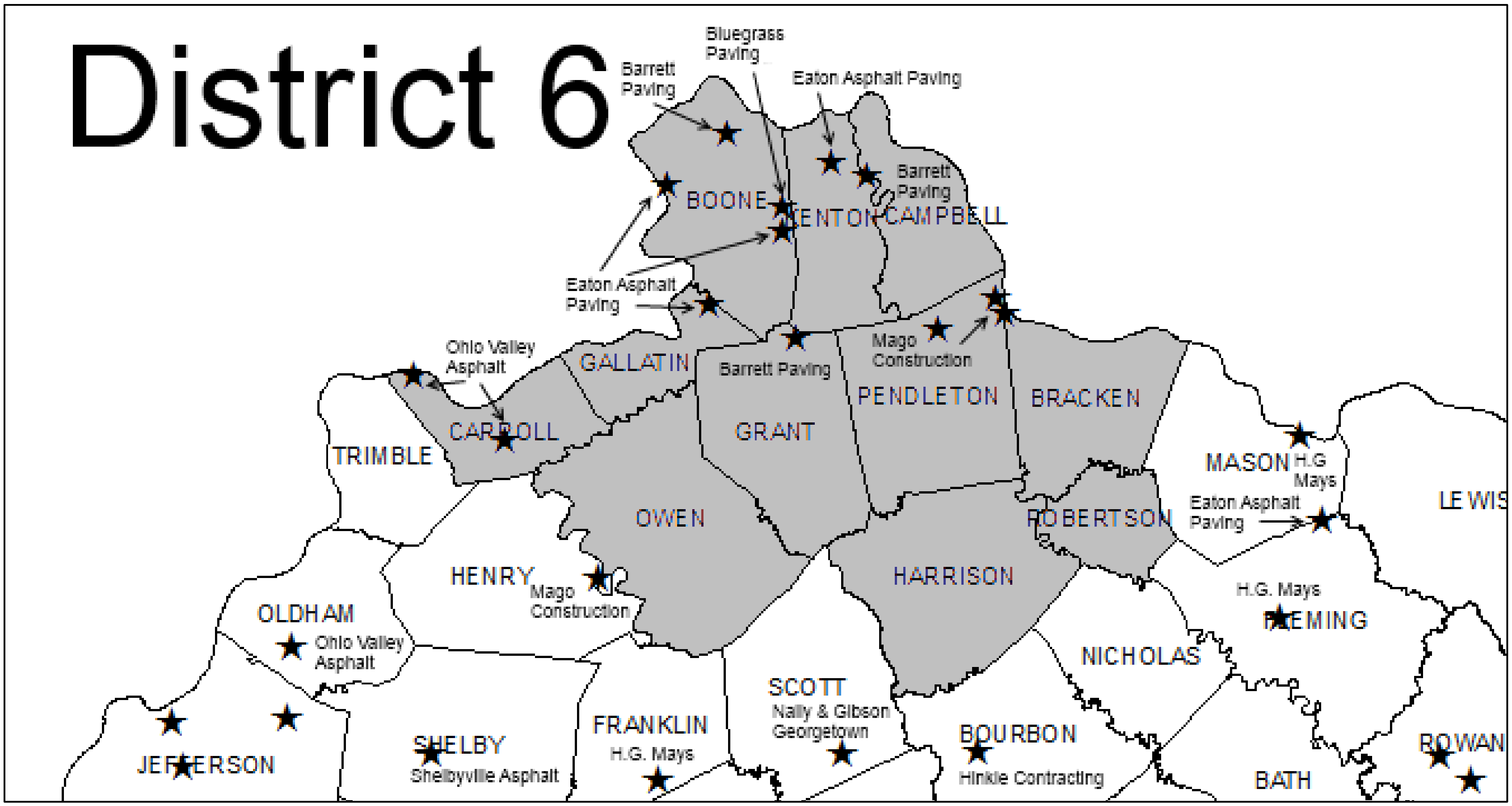


Figure 9: Barrett Paving Service Area

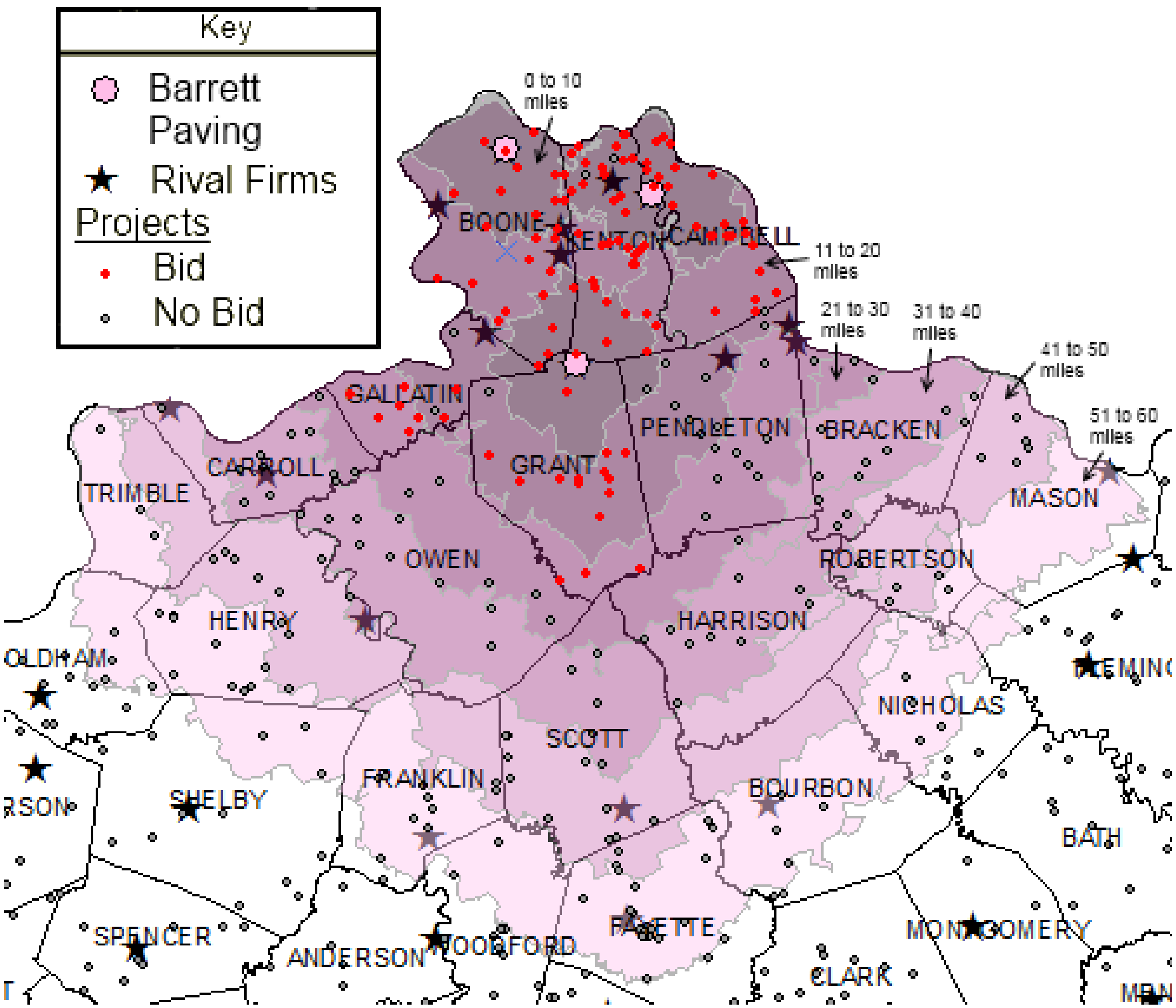


Figure 10: Bluegrass Paving Service Area

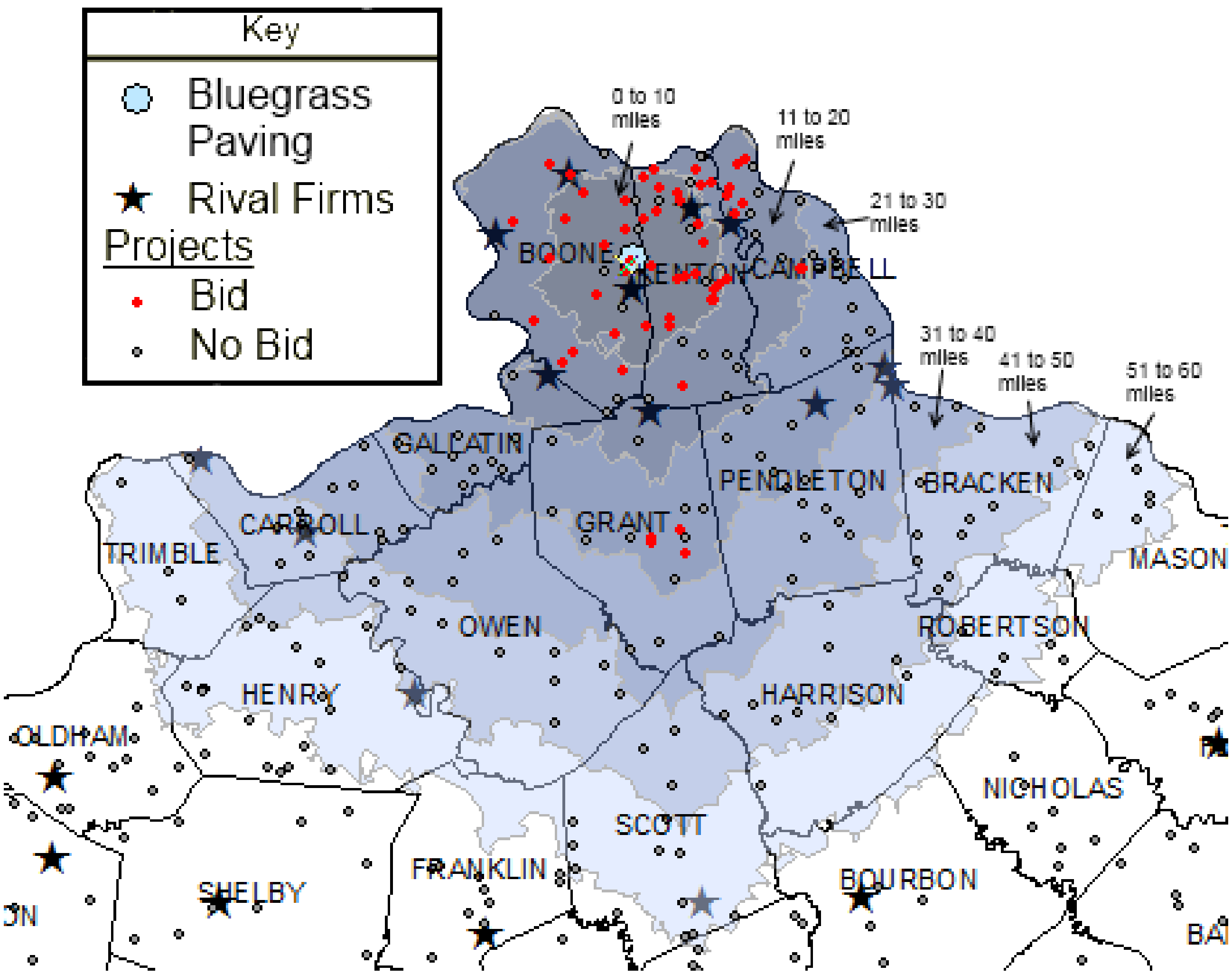


Figure 11: Eaton Asphalt Paving Service Area

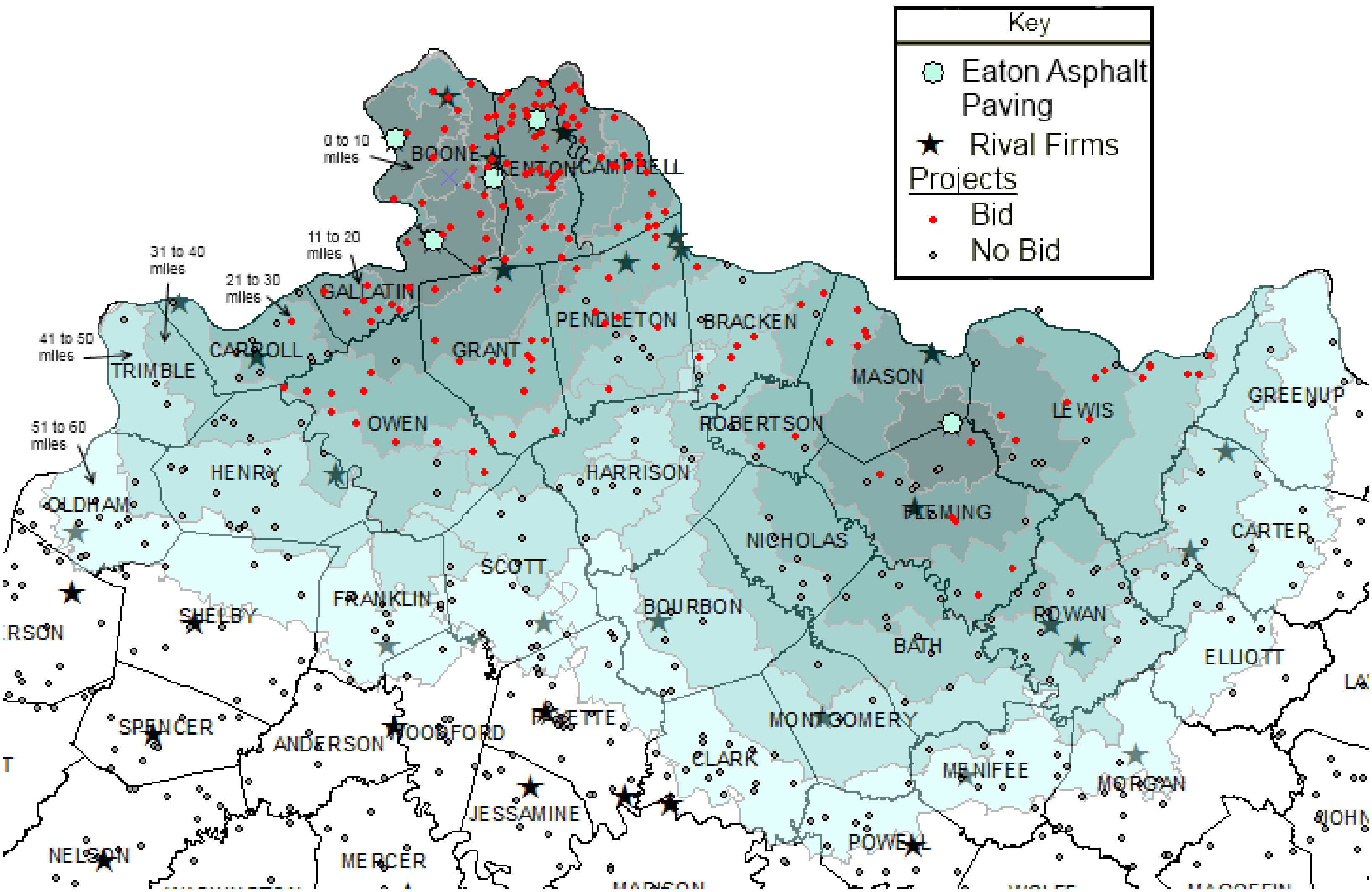


Figure 12: Central Kentucky (District 4) Counties, Firms, and Asphalt Plants

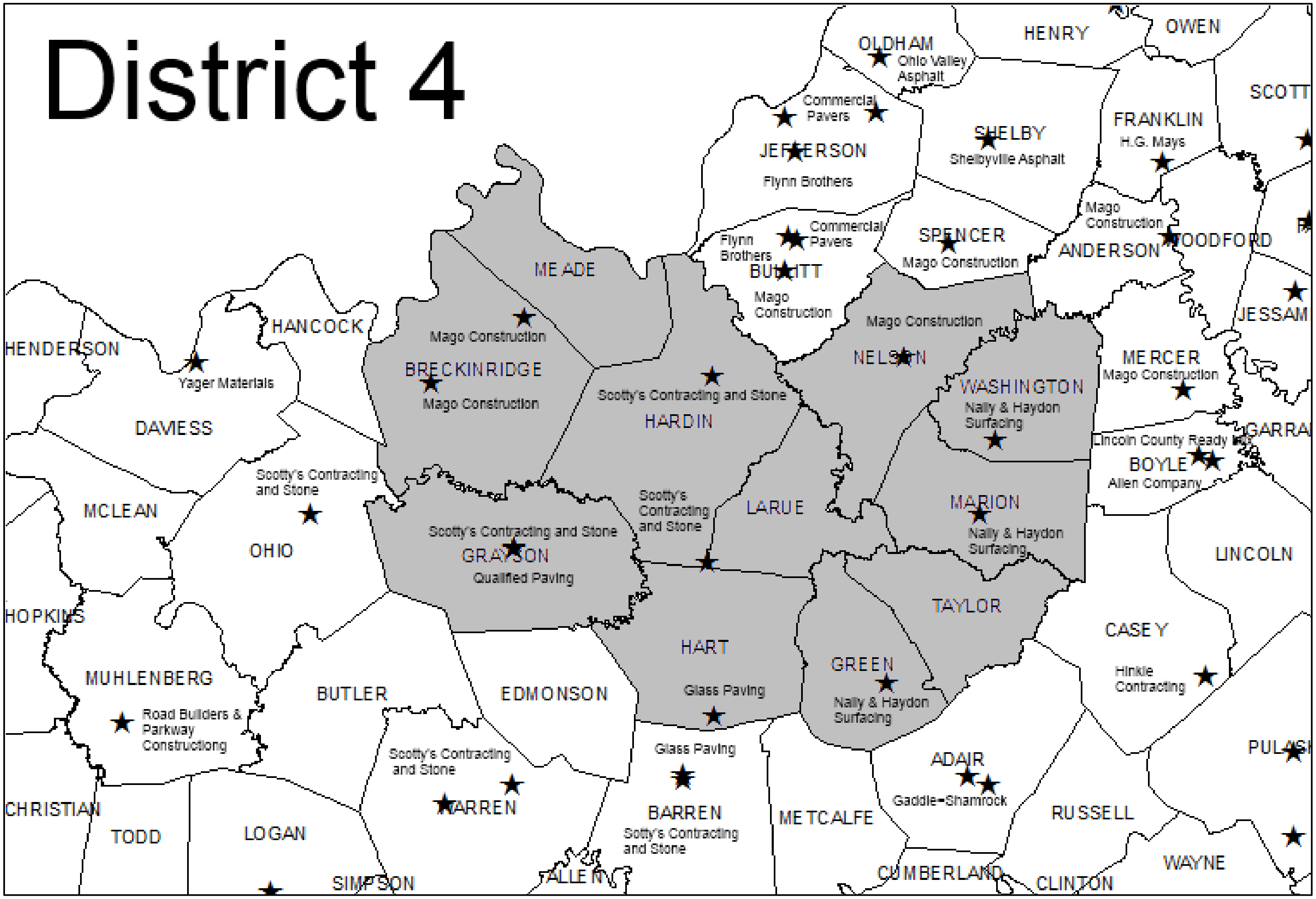


Figure 13: Nally & Haydon Surfacing Service Area

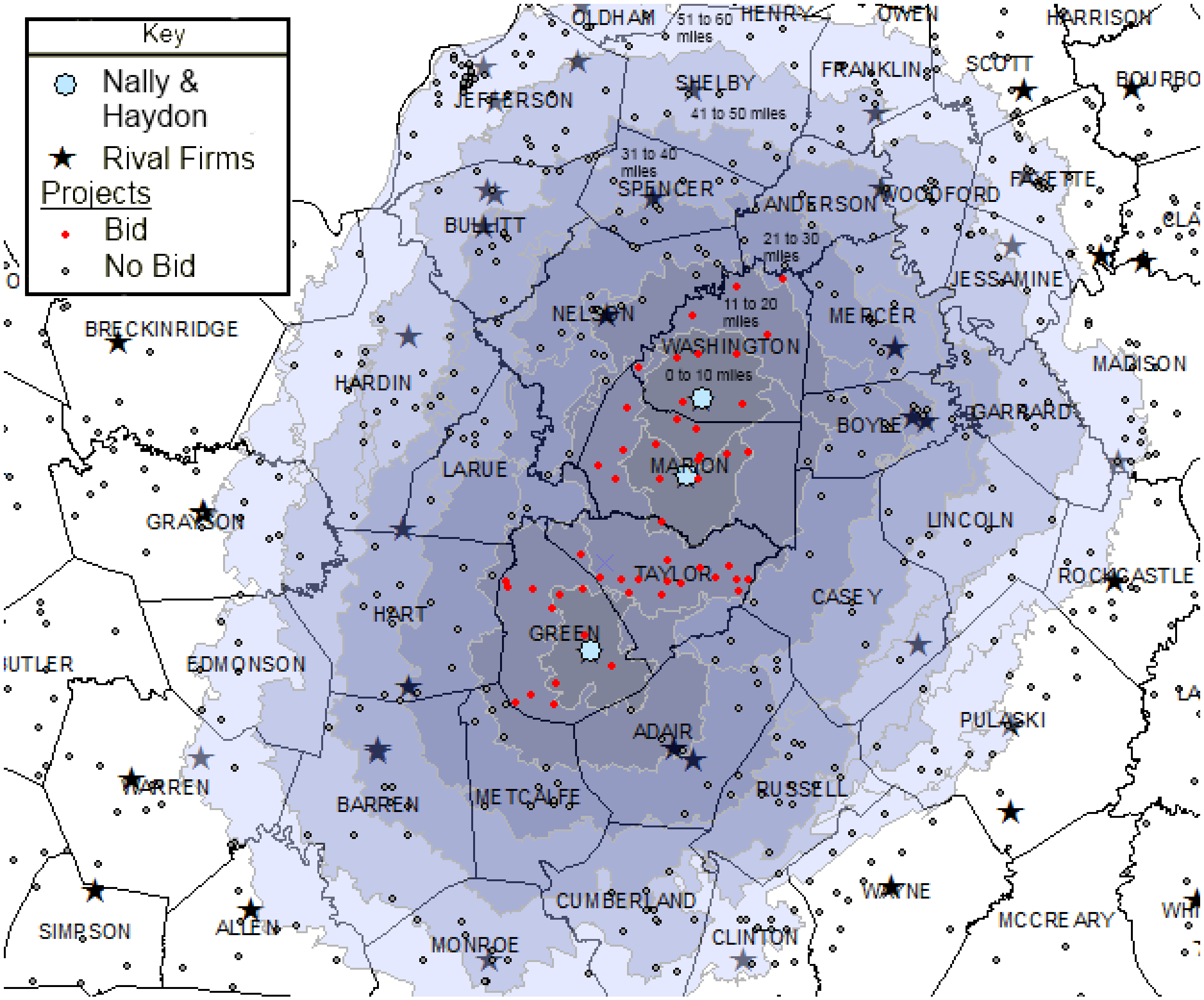


Figure 14: Eastern Kentucky (District 12) Counties, Firms, and Asphalt Plants

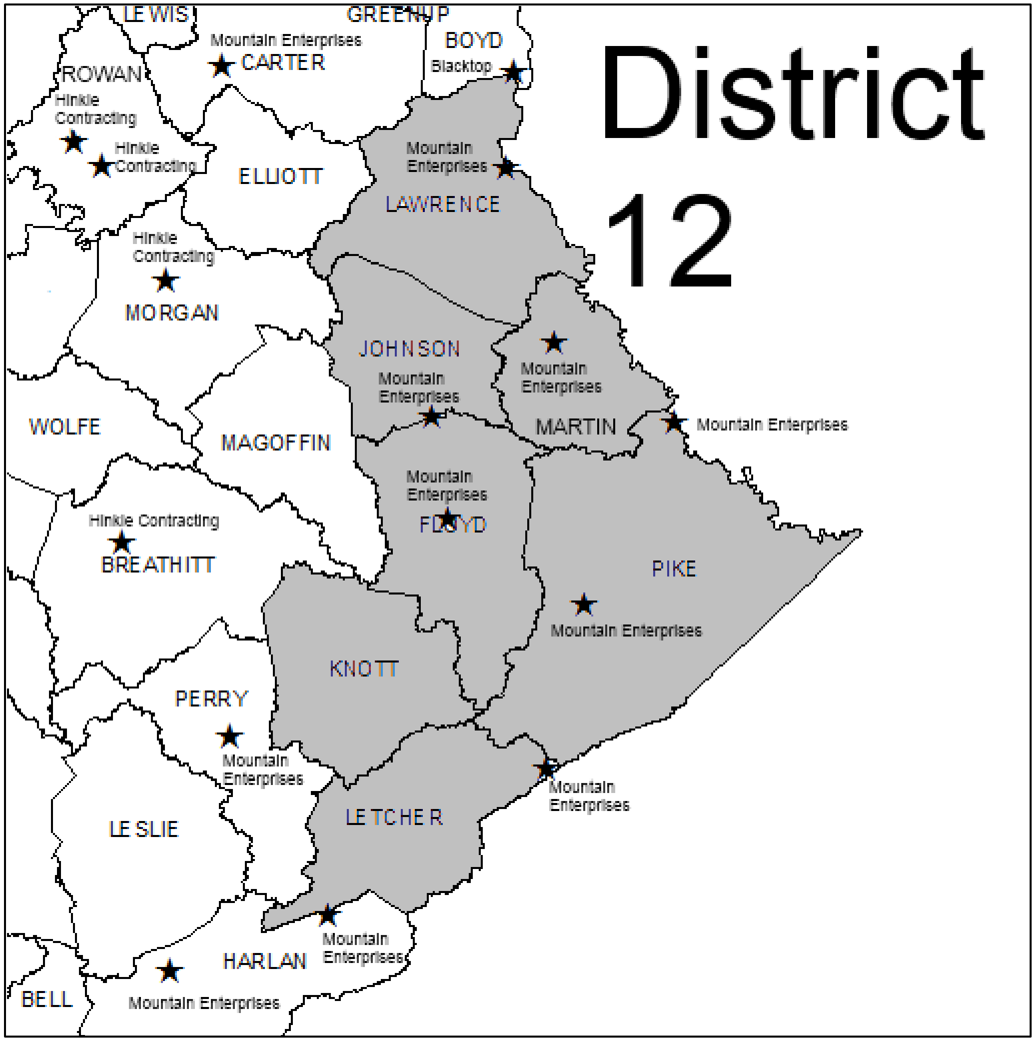
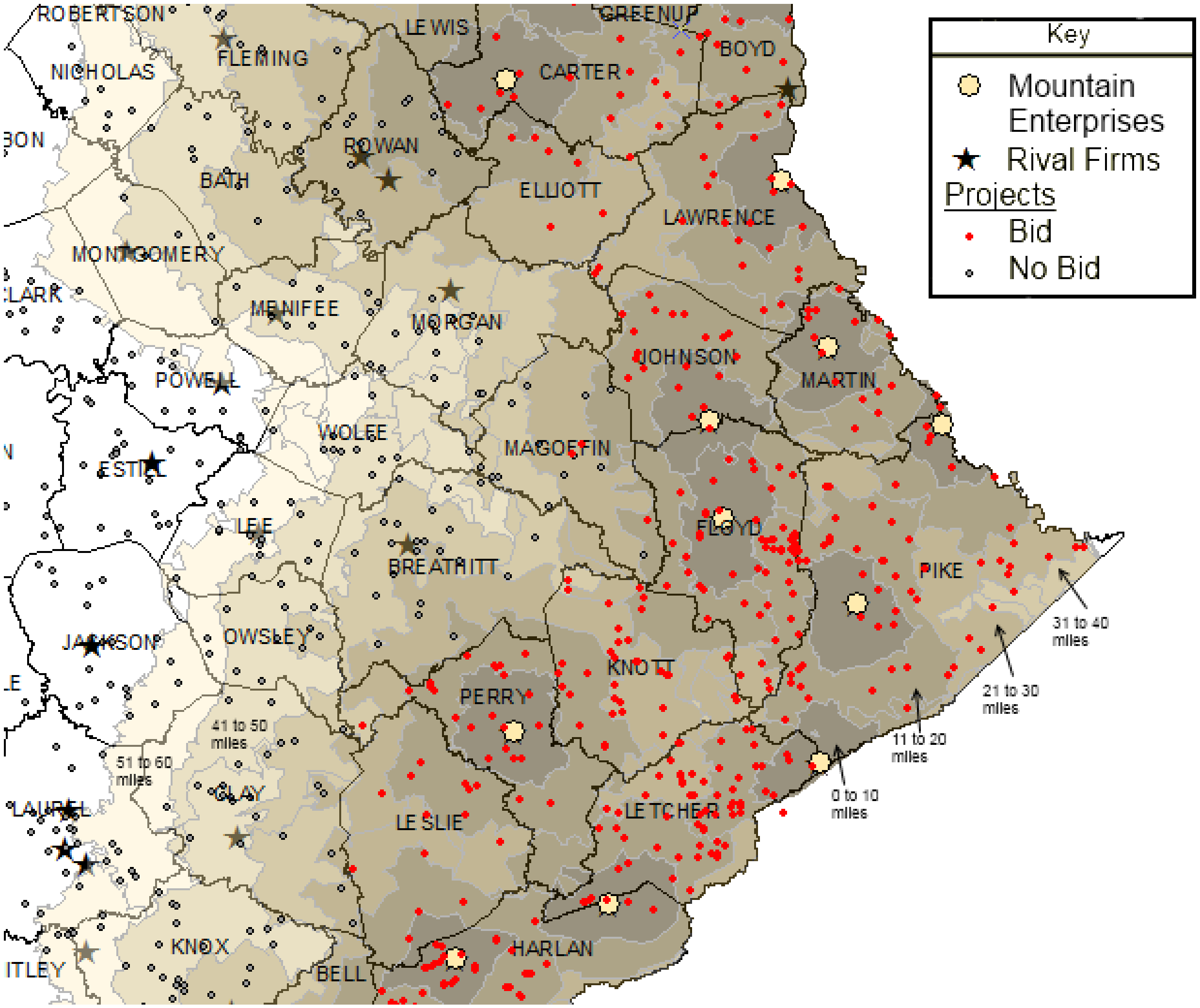


Figure 15: Mountain Enterprises Service Area



Appendix A-1: Diagram of Asphalt Paving

Did You Know?

The Asphalt Paving Train

1. Hot Mix Asphalt is manufactured in a plant, discharged into the dump truck, and transported to the project location. The mixture is typically heated to a temperature between 275 and 350 degrees Fahrenheit.

3. The truck gate is released, and the hot mix asphalt is discharged from the truck into the paver hopper. To avoid segregation of the mixture, the material should be allowed to "flood" the hopper and not "dribble" out of the truck.

5. The dump man uses hand signals to direct the truck driver's location and when and how much to raise and lower the truck bed.

8. The first roller is called the "breakdown roller" and provides the primary compaction (95 percent or more of specified density) of the mixture by applying weight – and sometimes vibration – to the mat.

10. Behind the rolling operation, quality control technicians from the contractor will typically perform density testing or obtain core samples from the roadway. Asphalt pavements are typically ready for traffic once the mixture has cooled below 150 degrees - usually in a few short hours.

2. The truck driver backs up just short of the paver – the driver should be careful not to bump the paver. Once the paver makes contact with the truck, the driver raises the bed. The truck driver applies the brakes gently, and the tractor unit on the paver pushes the truck forward.

4. The hot mix asphalt material flows from the hopper along the slat conveyors to the augers and eventually to the screed at the rear of the paver. A continuous, non-stop paving process ensures a quality product.

6. The free-floating (self-leveling) screed unit strikes off the material to create a smooth mat and provides initial compaction of the mixture. The screed also sets thickness, width and creates a smooth, uniform mat.

7. Paving crew members monitor the mixture for temperature and thickness and perform raking when necessary. Thin resurfacing may be accomplished in one pass, but thicker sections (for rehabilitation or new construction) may require multiple passes of the paver.

9. Most contractors will have two or three rollers on a project. The second roller is called the "intermediate roller" and provides the balance of the required density to the mixture. The final roller is called the "finish roller," and its purpose is to remove any remaining roller marks and provide smoothness to the pavement.

PAIKY PLANTMIX ASPHALT INDUSTRY OF KENTUCKY
P.O. Box 286, 119 W. Broadway, Depot Place, Frankfort, KY 40602
Tel (502) 223-3415 Fax (502) 223-2370 e-mail: info@paiky.org www.paiky.org

Appendix A-2: Asphalt paving bids let by county status in all 50 states

	# of Counties	% single-bid contracts (AASHTO Survey)	Contracts by county	Department of Transportation website	Notes
Alabama	67		Yes	www.dot.state.al.us	Most asphalt projects are typically in one county
Alaska	29		No	www.dot.state.ak.us	They group projects into three regions
Arizona	15		Could not be determined	www.azdot.gov	Could not determine from Arizona DOT website
Arkansas	75	11%	Yes	www.arkansashighways.com	Most asphalt projects are typically in one county
California	58		No	www.dot.ca.gov	Does not seem restricted to county
Colorado	64	29%	Yes	www.coloradodot.info	Most asphalt projects are typically in one county
Connecticut	8		No	www.ct.gov/dot	Does not seem restricted to a specific county
Delaware	3		Yes	www.deldot.gov	Most asphalt projects are typically in one county
Florida	67	10%	Yes	www.dot.state.fl.us	Most asphalt projects are typically in one county
Georgia	159		Yes	www.dot.state.ga.us	Most asphalt projects are typically in one county
Hawaii	4		Yes	www.hawaii.gov/dot	Most asphalt projects are typically in one county
Idaho	44		Yes	www.itd.idaho.gov	Most asphalt projects are typically in one county
Illinois	102	30%	Yes	www.dot.il.gov	Most asphalt projects are typically in one county
Indiana	92		Yes	www.in.gov/dot	Most asphalt projects are typically in one county
Iowa	99	19%	Yes	www.iowadot.gov	Most asphalt projects are typically in one county
Kansas	105		Yes	www.ksdot.org	Most asphalt projects are typically in one county
Kentucky	120	70%	Yes	www.transportation.ky.gov	Most asphalt projects are typically in one county
Louisiana	64	34%	Yes	www.dotd.la.gov	Most asphalt projects are typically in one parish
Maine	16	80%	Yes	www.maine.gov/mdot/	Most asphalt projects are typically in one county
Maryland	24		Yes	www.roads.maryland.gov	Most asphalt projects are typically in one county
Massachusetts	14		No	www.massdot.state.ma.us/Highway/	They are not county specific. Could be on city or town level
Michigan	84		Yes	www.michigan.gov/mdot	Most asphalt projects are typically in one county
Minnesota	87		Mixed	www.dot.state.mn.us	I found some asphalt projects that were in multiple counties. A lot of asphalt projects were just in one county.
Mississippi	82	80%	Yes	www.gomodot.com	Most asphalt projects are typically in one county
Missouri	115	10%	Mixed	www.modot.org	I found some asphalt projects that were in multiple counties. A lot of asphalt projects were just in one county.
Montana	56	30%	Yes	www.mdt.mt.gov	Most asphalt projects are typically in one county
Nebraska	93	20%	Yes	www.dor.state.ne.us	Most asphalt projects are typically in one county
Nevada	17		Yes	www.nevadadot.com	Most asphalt projects are typically in one county
New Hampshire	10		Mixed	www.nh.gov/dot/	I found most asphalt resurfacing projects were in multiple counties.
New Jersey	21		Yes	www.state.nj.us/transportation	Most asphalt projects are typically in one county
New Mexico	33		Yes	www.nmshtd.state.nm.us	Most asphalt projects are typically in one county
New York	58		Yes	www.nysdot.gov	Most asphalt projects are typically in one county
North Carolina	100	21%	Yes	www.ncdot.gov	Most asphalt projects are typically in one county
North Dakota	53		Yes	www.dot.nd.gov/	Most asphalt projects are typically in one county
Ohio	88		Yes	www.dot.state.oh.us	Most asphalt projects are typically in one county
Oklahoma	77		Yes	www.okladot.state.ok.us	Most asphalt projects are typically in one county
Oregon	36		Yes	www.oregon.gov/ODOT	Most asphalt projects are typically in one county
Pennsylvania	67		Could not find info	www.dot.state.pa.us	Information no readily available on website
Rhode Island	5		Could not be determined	www.dot.state.ri.us	It does not appear that counties are an issue
South Carolina	46	10%	Yes	www.dot.state.sc.us	Most asphalt projects are typically in one county
South Dakota	66		Mixed	www.sddot.com	I found some asphalt projects that were in multiple counties. A lot of asphalt projects were just in one county.
Tennessee	95	30%	Yes	www.tdot.state.tn.us	Most asphalt projects are typically in one county
Texas	254	37%	Yes	www.dot.state.tx.us	Most asphalt projects are typically in one county
Utah	29	33%	Yes	www.udot.utah.gov	Most asphalt projects are typically in one county
Vermont	14	23%	Mixed	www.aot.state.vt.us	I found some asphalt projects that were in multiple counties. A lot of asphalt projects were just in one county.
Virginia	95	30%	Yes	www.virginiadot.org	Most asphalt projects are typically in one county
Washington	39		Mixed	www.wsdot.wa.gov	I found some asphalt projects that were in multiple counties. A lot of asphalt projects were just in one county.
West Virginia	55	33%	Yes	www.transportation.wv.gov	Most asphalt projects are typically in one county
Wisconsin	72		Yes	www.dot.state.wi.us	Most asphalt projects are typically in one county
Wyoming	23		Could not find info	www.dot.state.wy.us	Information no readily available on website

Appendix A-3: Probit results for 11 firms in Kentucky – without county variables

	ATS	*The Allen Company*	*Commercial Pavers*	*Flynn Brothers*	*HG Mays*	*Mago Construction*	*The Walker Company*	*Hinkle Contracting*	*Mountain Enterprises*	*Elmo Greer & Sons*	*Kay & Kay Contracting*
Number of observations	84	150	94	101	122	332	110	336	204	169	121
X^2	30.73	43.04	22.74	31.46	33.52	92.21	23.77	84.3	40.47	43.03	46.64
Degrees of freedom	4	4	4	4	4	4	4	4	4	4	4
Pseudo R^2	0.5509	0.2269	0.3721	0.3467	0.3761	0.3913	0.5997	0.4394	0.4554	0.7992	0.5264
Log likelihood	-21.692709	-76.622434	-40.252684	-40.683752	-47.698676	-125.15116	-22.579429	-119.50692	-63.065214	-23.210401	-35.280282
Variables											
Log of Distance	-1.5948 ***	-0.9821 ***	-0.5836 ***	-0.5741 ***	-1.8270 ***	-1.9964 ***	-3.5958 ***	-1.9388 ***	-2.2940 ***	-3.7162 ***	-0.9562 ***
	(0.313)	(0.173)	(0.162)	(0.169)	(0.319)	(0.210)	(0.783)	(0.222)	(0.377)	(0.606)	(0.204)
Jobs Under Contract	-0.1641	-0.0516	0.0172	0.3842	-0.0778	0.0008	0.0726	-0.0186	-0.0841 ***	-0.0163	0.1147
	(0.133)	(0.063)	(0.105)	(0.237)	(0.092)	(0.044)	(0.078)	(0.034)	(0.031)	(0.066)	(0.087)
Log of Engineer's Estimate	0.2645 *	-0.3265 ***	-0.2570 *	-0.7818 ***	0.0027	-0.0526	0.1000	-0.2231 **	0.0057	-0.0874	-0.3401 *
	(0.160)	(0.120)	(0.159)	(0.213)	(0.151)	(0.113)	(0.211)	(0.094)	(0.140)	(0.216)	(0.175)
Log of Number of bid proposals	0.5714	0.9991 ***	2.1905 ***	1.8742 ***	0.6864 **	-0.0992	1.2865 *	-0.1435	-0.7313	1.0535 *	2.6252 ***
	(0.583)	(0.299)	(0.738)	(0.441)	(0.313)	(0.163)	(0.770)	(0.318)	(0.476)	(0.598)	(0.490)
Constant	-0.7245	6.2436 ***	2.2937	8.5928 ***	4.3614 **	5.4767 ***	7.6902 ***	8.0549 ***	8.1287 ***	10.8595 ***	5.2473 **
	(2.097)	(1.753)	(2.105)	(2.625)	(2.174)	(1.544)	(2.920)	(1.403)	(2.220)	(3.356)	(2.378)

Note: Significance: * (10%), ** (5%), *** (1%); Robust standard errors are in parentheses.

Appendix A-3 (continued): Probit results for 11 firms in Kentucky – with county variables

	ATS	*The Allen Company*	*Commercial Pavers*	*Flynn Brothers*	*HG Mays*	*Mago Construction*	*The Walker Company*	*Hinkle Contracting*	*Mountain Enterprises*	*Elmo Greer & Sons*	*Kay & Kay Contracting*
Number of observations	46	61	94	101	98	326	97	262	164	56	121
X^2	44.11	10.25	26.89	34.1	21.2	118.48	23.04	58.72	20.65	-	-
Degrees of freedom	5	5	7	7	5	6	5	5	6	1	6
Pseudo R^2	0.5707	0.1059	0.4451	0.4002	0.2749	0.5939	0.3726	0.3549	0.3661	1	0.6333
Log likelihood	-13.670515	-31.385997	-35.572664	-37.356382	-30.413652	-80.585792	-20.195474	-68.820542	-27.210982	-2.298E-09	-27.317196
Variables											
Log of Distance	-0.3856	0.0242	0.2594	-0.5057	-0.3546	-1.5034 ***	-2.7961 ***	-0.5145	-1.4758 ***	-28.5669	-1.6358 ***
	(0.431)	(0.258)	(0.383)	(0.371)	(0.434)	(0.270)	(0.901)	(0.347)	(0.570)	-	(0.364)
Jobs Under Contract	-0.3345 **	-0.1445	-0.0192	0.4772 *	0.0075	0.0216	0.0773	-0.0190	-0.1200 **	2.5106	0.1619
	(0.155)	(0.109)	(0.108)	(0.258)	(0.129)	(0.049)	(0.087)	(0.045)	(0.053)	-	(0.107)
Log of Engineer's Estimate	0.0394	-0.1421	-0.2388	-0.7629 ***	0.1561	0.0322	0.1195	-0.1997	-0.0714	-0.5334 ***	-0.3858 **
	(0.162)	(0.188)	(0.150)	(0.221)	(0.154)	(0.125)	(0.220)	(0.133)	(0.178)	(0.107)	(0.187)
Log of Number of bid proposals	1.0321 ***	-0.9232 **	2.0619 *	2.9523 ***	1.1301 ***	0.4931 **	1.9340 ***	-0.4464	-1.2636 **	26.9769	3.2301 ***
	(0.391)	(0.463)	(1.242)	(0.892)	(0.410)	(0.245)	(0.642)	(0.456)	(0.593)	-	(0.577)
Project in same county-no rival	2.4934 ***	-1.0616 ***			‡(20)	1.1651 ***	‡(13)	‡(74)	0.4559	‡(60)	
	(0.850)	(0.395)				(0.362)			(0.342)		
Project in same county-rival		‡(11)	1.7551 ***	0.6734	‡(4)	‡(6)			-0.2051	‡(12)	6.2485 **
			(0.661)	(0.779)					(0.661)		(2.598)
Project in adjacent county-rival	†(38)	†(78)	*reference*	*reference*	-1.5170 ***	-1.5848 ***	-0.8078 **	-2.0112 ***	†(43)	†(41)	8.4220 ***
					(0.407)	(0.260)	(0.406)	(0.384)			(2.622)
Project in adjacent county-no rival	*reference*	*reference*			*reference*	*reference*	*reference*	*reference*	*reference*	*reference*	*reference*
Commercial Pavers bid proposal				-0.6143							
				(0.544)							
Flynn Brothers bid proposal			0.2036								
			(0.486)								
Gohmann bid proposal			-0.6713	-1.4996 **							
			(1.041)	(0.644)							
Constant	-0.6343	3.8685	0.1142	8.1493 **	-2.3803	2.8748	5.2283	4.0287 *	7.8652 ***	31.0337 ***	-0.5507
	(2.321)	(2.565)	(2.159)	(3.216)	(2.463)	(1.757)	(3.414)	(2.159)	(2.451)	(1.774)	-

Note: Significance: * (10%), ** (5%), *** (1%); Robust standard errors are in parentheses.
†: Variable dropped because "predicts failure perfectly." Number in parenthesis is the number of observations dropped.
‡: Variable dropped because "predicts success perfectly." Number in parenthesis is the number of observations dropped.