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Will Competitive Bidding Decrease Medicare Prices?

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Recent measures to reduce Medicare spending include the use of competitive bidding in determining reimbursement prices. Several competitive bidding experiments have been conducted by the Centers for Medicare and Medicaid Services (CMS) to determine reimbursement prices. This paper investigates the use of competitive bidding to set reimbursement prices for durable medical equipment, prosthetics, orthotics, and supplies. First, the competitive bidding process is examined on a theoretical level. It is shown that the CMS competitive bidding process (auction) is inefficient, leads to price increases, and may cause decreases in the quality of services. Next, data supporting the theoretical predictions are presented. Finally, we suggest that a descending variant of the Ausubel, Cramton, and Milgrom (2006) clock-proxy auction be used.

JEL Classification: I11, I18, H51, D44

1. Introduction

The Balanced Budget Act of 1997 granted the Centers for Medicare and Medicaid Services (CMS) congressional approval to implement up to three demonstration projects to investigate competitive bidding as a means of choosing Medicare providers. Officially deemed Durable Medical Equipment and Prosthetics, Orthotics, and Supplies (DMEPOS) Competitive Bidding Demonstration Projects, three experiments have been completed. Two projects were conducted in the Polk County, Florida, area (Polk County Round I and Polk County Round II), and another was implemented in the San Antonio, Texas, area (San Antonio).

Experimentation with DMEPOS, in which area Medicare expenditures currently total over $6 billion, is based on CMS's expectation of significant savings relative to the past procedure for setting reimbursement prices. This expectation of savings is no more evident than in the following excerpt from the Request for Bids sent to potential Polk County suppliers in January of 1999. It stated, ‘‘Medicare payments for DMEPOS are based on outdated fee

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schedules required by law. Studies by the General Accounting Office (GAO) and the Office of the Inspector General have found that payments allowed currently by Medicare fee schedules often include unreasonably high markups. These studies show that Medicare payments for certain DMEPOS items are greater than payments made by other insurers and sometimes greater than prices charged at retail outlets for customers who are not Medicare beneficiaries.''

The decision to use competitive bidding as an alternative to outdated, inflated fee schedules was based on two appealing properties of competitive bidding. First, competitive bidding is commonly lauded for the competition it promotes, and CMS expected lower reimbursement prices to result from increased competition.[1] Second, the competitive bidding procedure gives CMS a hand in determining firm eligibility, thus ensuring quality service for Medicare recipients and protecting against collusion. The premise of our paper is that while utilizing competitive bidding in the Medicare process is an excellent idea, the format with which CMS experimented hinders both CMS and its beneficiaries from achieving greater savings.

The CMS bidding process consists of three stages. A pre-screening stage determines each firm's ability to supply quality service to Medicare beneficiaries within different categories of goods (e.g., surgical supplies, oxygen equipment). In stage 2, eligible firms submit bids on each and every individual good within the categories on which they are bidding, and winners are determined. Finally, the price of an individual good is determined using a weighted average of the winners' bids on that good.[2]

While the pre-screening stage appropriately identifies quality Medicare providers, the rules for determining winners and setting prices are complex. Both processes involve an aggregation of bids on individual goods within a given product category. The process for determining winners requires the calculation of a ''composite bid'' (weighted average)[3] for each firm based on its individual bids on the different goods within a category. Those firms with the lowest composite bids win the bidding process and are deemed official Medicare providers. The price that official Medicare providers are allowed to charge for individual *units* of a *good* is then a weighted average of the winning bids on that *good*.[4]

In designing the competitive bidding experiment, CMS envisioned a process in which the individual bids submitted by firms would represent the lowest price at which they were willing to supply each good. Unfortunately, our theoretical models show that equilibrium bidding is conflated by the aggregation rules and that truthful bidding of costs is not elicited by the CMS rules. This, in turn, implies that there are circumstances in which the CMS mechanism will fail to select the lowest cost providers.

The root of the problem is that a firm's composite bid, and not its individual component bids, determines whether or not the firm is given Medicare provider status. Thus, while the individual bids are used to calculate Medicare prices, the composite bid determines whether or not the firm becomes a Medicare provider. As the composite bid is a linear function of individual bids, this avails the firm of a number of ways of achieving a targeted composite bid

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[1] Of course, lower prices do not guarantee lower expenditures if demand is elastic. However, it is commonly noted that demand for medical supplies tends to be inelastic.

[2] Unlike many auctions, the CMS DMEPOS auction does not generate revenue. The bidding process is intended to determine which firms can supply the goods at the lowest cost and set the prices of the goods accordingly.

[3] Weights on individual bids are determined by CMS prior to bidding and represent anticipated demand for the good relative to the anticipated demand for the product category as a whole.

[4] We are careful to maintain the term *good* to designate tangibly different products, while the term *unit* is used to keep track of quantities of a specific *good*.

regardless of the cost of supplying individual goods. At best, this leads to vast uncertainty regarding prices on individual goods. At worst, it opens the door for "gaming" of the system.

Instances of gaming linear composite-type bidding systems have been documented for auctions of U.S. timber (see Baldwin, Marshall, and Richard 1997; Athey and Levin 2001) and California electricity (see Bushnell and Oren 1994; Gribik 1995). The basic idea extends to the CMS rules, and our models below show that "gaming" is in fact optimal behavior for firms. Specifically, if a firm believes that CMS has underestimated relative demand for a good, it can increase its bid on that good while lowering its bid on a good for which it believes relative demand forecasts are too high, all while simultaneously maintaining its targeted composite bid. In doing so, it will be able to increase the price of the good that it believes will have relatively high demand by simply lowering its bid on the good for which it forecasts relatively low demand. This is clearly a profitable strategy that has adverse pricing repercussions.

The main prediction from our model is that while the CMS format will achieve price reductions on some goods, this will most likely occur at the expense of increased prices on other goods. Using data from completed demonstration projects, we establish preliminary evidence that this is the case, adding fuel to the growing literature on the inefficient pricing structure within the Medicare program (see Dor, Held, and Pauly 1992; Cutler 1995; Dor and Watson 1995; Dor 2004). We find that price increases occur often and that the gains from competitive bidding (in its current form) may not be as large as CMS had hoped. The fact that when a firm bids high on one good it must correspondingly bid low on another good in order to reach its targeted composite bid introduces additional, less quantifiable ramifications as well. Specifically, if the price of a good is bid too low, firms may tacitly avoid supplying it, thereby increasing consumer search costs and decreasing quality of service.[5]

Finally, it is our contention that the shortcomings of the CMS design relate to a fundamental misunderstanding of auctions. A common misconception is that the desirable properties of single-unit auctions extend to multi-unit auctions (see Ausubel and Cramton 2002, p. 1, for a discussion). However, recent theoretical breakthroughs show that there are actually very few multi-unit auctions that possess the famous efficiency and revenue-generating properties of single-unit auctions. In fact, the majority of multi-unit auctions are inefficient and can deliver vastly different expected outcomes (see Engelbrecht-Wiggans and Kahn 1995; Noussair 1995; Katzman 1999; Ausubel and Cramton 2002). Even the famed Vickrey (1961, 1962) auction, lauded for eliciting bids equal to costs/values, is susceptible to collusion and third-party manipulation (see Graham and Marshall 1987; Rothkopf, Teisberg, and Kahn 1990). Fortunately, recent developments in auction design by Ausubel (2004), Reny and Perry (2005), Ausubel and Milgrom (2006), and Ausubel, Cramton, and Milgrom (2006) have addressed the shortcomings of existing auction formats and provide a wealth of realistic alternatives. In the end, we encourage CMS to investigate the merits of these new bidding processes.

[5] Outright denial of service would certainly have negative future impacts on a firm dealing with CMS. However, other methods, such as keeping the customer on hold indefinitely, may be as effective and less easily identified. In addition, poor service to a customer on the first transaction (perhaps in terms of late delivery) may encourage the customer to seek out other, less convenient suppliers. While it may take years to analyze the impact of the auctions on service quality, in a baseline study, Hoerger, Finkelstein, and Bernard (2001) found that prior to the inception of the demonstration project, Medicare beneficiaries were highly satisfied with their Medicare providers, thus providing a benchmark to which post-auction surveys can be compared. This topic is discussed in greater detail in section 5.

Table 1. Product Categories by Project (Values Indicate No. of Items)

Category	Polk County Round I	San Antonio	Polk County Round II
Hospital beds and accessories	31	18	13
Oxygen equipment and supplies	15	10	8
Enterals	25		
Urologicals	40		22
Surgical dressing and supplies	52		28
Manual wheelchairs and accessories		60	
Non-customized orthotic devices		46	
Nebulizer inhalation drugs		27	

2. The CMS Bidding Process

The competitive bidding projects were run in Polk County, Florida, and San Antonio, Texas. The product categories targeted by CMS for the Polk County Round I, San Antonio, and Polk County Round II projects appear in the first column of Table 1. The choice of these categories was based on the anticipation of significant savings on these types of equipment. Any firm wishing to provide goods in the categories listed in Table 1 to Medicare beneficiaries in Polk County or San Antonio during the project was required to participate in the process. That is, firms not submitting bids or firms who were unsuccessful at the auction could *not* supply any good in the categories listed in Table 1 to Medicare beneficiaries in the respective regions.[6]

At the inception of a project, a Request for Bids (RFB) was sent out to potential suppliers. The RFB detailed the process that firms had to follow to be eligible for consideration; it also explained the overall process. In addition, past demand data were provided to aid firms in estimating demand in subsequent years. Included in these data were the turnover of beneficiary users for each good within each product category, the total number of beneficiary users for all goods in each product category, the number of new beneficiary users for each good in a product category, and trends in beneficiary usage.

The initial stage of each project focused on eligibility. CMS's goal was to choose firms that would provide reliable, quality service to Medicare beneficiaries. At a minimum, firms had to comply with all state and federal regulatory requirements, all Medicare and Medicaid statutes and regulations, all billing guidelines pertaining to Medicare, and all National Supplier Clearinghouse standards. If a firm met all of these criteria, it was invited to submit bids.[7]

Bidding by eligible firms was done by category. Firms that submitted bids in a given product category were directed to submit a bid on *every* individual good in that category. That is, a firm that bid on one good in a category had to bid on all goods in that category. Once bids were received, they were reviewed, and a 10-day grace period was given, during which the firms were allowed to amend or revise their bids. After that, all bids were final.

[6] The numerical entries in Table 1 denote the number of unique goods that were included in each category. The reader may be interested in noting that each category included both complement goods (e.g., hospital beds, hospital bed rails) as well as substitute goods (e.g., composite dressing without adhesive, composite dressing with adhesive).

[7] In fairness to smaller suppliers, those deemed eligible were allowed to form networks. To avoid anti-competitive behavior, a network's total market share could not exceed 25% of the Medicare market for any product category. Members of networks were not allowed to submit individual bids in addition to the network's bids.

CMS indicated that bids should represent the price below which the firm would not be able to supply that good.[8]

Before going into the details of the bidding process, it will be helpful to point out a few important traits of this design. First, the process did not generate revenue; it allocated the right to be a Medicare provider, and bids were only used to select Medicare providers and to calculate the allowable reimbursement prices. Second, since CMS's goal was to reduce Medicare prices, it was looking to identify those producers that submitted the lowest bids. Finally, and most importantly, this process was multi-unit in nature, thereby limiting the applicability of a vast majority of the auction literature.

Upon receipt of all bids, a process was set in motion for determining winners and for subsequently setting prices. First, a firm's bids on individual goods in a category were used to form a "composite bid" for the firm in that category.[9] Calculation of the composite bid used CMS-specified weighting coefficients (that represented the anticipated demand for individual goods relative to demand in the category as a whole) and the firm's individual bids.

Consider a category with I distinct goods. Denote the weight assigned to good i by w_i. If $\hat{v}_i$ is the estimated volume for good i and $\hat{V}$ is the estimated volume for the entire product category, then w_i is calculated as $w_i = \hat{v}/\hat{V}$, which implies $\Sigma^I_{i=1}\ w_i = 1$. Inherently, CMS used estimated volume as a forecast of demand in the subsequent year.[10] The resulting weights were given to the firms as part of the RFB and were therefore known to the firms prior to bid submission.

CMS next calculated weighted bids ($\tilde{b}_{in}$), using each firm's (n) individual bids (b_{in}), as $\tilde{b}_{in} = w_i b_{in}$. Finally, the firm's composite bid, B_n, was calculated as $B_n = \Sigma^I_i\ \tilde{b}_{in}$. After they had been calculated, the composite bids were placed in ascending order. Using demand information for each good, CMS determined how many firms would be necessary to meet demand in each category. Denote this number of firms by M. The Mth lowest composite bid was deemed the cutoff composite bid, $\bar{B}$, in that category, and the firms submitting the M lowest bids became Medicare providers of goods in that category. CMS refers to bids at or below the cutoff composite bid as being in the "competitive range."

The final step in the process was determining the prices at which providers would be reimbursed. First, a ratio representing the competitiveness of each firm's composite bid was calculated. Indexing firms by $m = 1,\ldots, M$, the ratio (r_m) is $r_m = \bar{B}/B_m \geq 1$. Next, an adjusted bid price (a_{im}) was calculated for each good (i) using the firm's competitiveness ratio and its original bid for that good, such that $a_{im} = b_{im} \times r_m$. The demonstration price that was set on each good was the average of the winning firms' adjusted bid prices, or $p_i = \Sigma^M{}_{m=1}\ a_{im}/M$.

Finally, the amount reimbursed by Medicare to the winning firms was equal to 80% of the demonstration price, p_i, and the beneficiary co-payment was 20%. The demonstration prices, Medicare reimbursement, beneficiary's co-payment, and pre-experiment prices for each project were listed on the CMS DMEPOS Projects website, available at http://www.cms.hhs.gov/DemoProjectsEvalRpts/MD/list.asp (CMS 2006). These data are analyzed in section 5.

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[8] A seemingly minor but related rule turns out to be very important in our empirical analysis. As bids were expected to represent the cost of supplying the good, bids below wholesale prices were not allowed. Unfortunately for our empirical analysis, CMS gave no specifics as to what these wholesale prices were, and internet searches of wholesale prices at the time produced a wide variety of possibilities.

[9] CMS refers to the composite bid as a composite bid price. However, we will refer to it as the composite bid so that we may reserve the word price for that amount paid for one *unit* of a *good* by the beneficiary.

[10] This is consistent with how CMS calculated the weights for the San Antonio and Polk County Round II projects. In the Polk County Round I project, the weights were the estimated claims for an item divided by the total estimated claims for the total category.

3. Full Information

The model presented in this section is intended to convey our basic results to a general audience. The model is one of full information with respect to bidder costs. That is, every firm knows every other firm's marginal cost structure.[11] We do allow for differences between firm estimates of volume and CMS estimates. Despite the difference in firm and CMS estimates, one can still think of this as a game with full information by assuming that the CMS weights were credibly fixed in the RFB before additional information allowed firms to obtain better estimates. Consider a case in which N firms compete to be suppliers of two different goods (goods 1 and 2) within the same product category. CMS has determined that two of the N firms will be chosen to supply the two goods. Each firm (n) is assumed to have the ability to supply half of the total volume of good i ($v_i/2$) at a constant marginal cost of c_{in}.[12] CMS has demand estimates of $\hat{v}_{1,CMS}$ and $\hat{v}_{2,CMS}$ that give a total volume estimate of $\hat{V}_{CMS} = \hat{v}_{1,CMS} + \hat{v}_{2,CMS}$ and weights $w_1 = \hat{v}_{1,CMS}/\hat{V}_{CMS}$ and $w_2 = \hat{v}_{2,CMS}/\hat{V}_{CMS}$. Firms have their own demand estimates, $\hat{v}_{1,firm}$ and $\hat{v}_{2,firm}$, that result in a total volume estimate of $\hat{V}_{firm} + \hat{v}_{1,firm} + \hat{v}_{2,firm}$ and weights $\gamma_1 = \hat{v}_{1,firm}/\hat{V}_{firm}$ and $\gamma_2 = \hat{v}_{2,firm}/\hat{V}_{firm}$. In order to limit complexity, we assume that each firm has the same estimates of relative demand, γ_1 and γ_2.

Strategies for firm n (=1,…, N) are bids b_{1n} and b_{2n}. These bids are aggregated using the weights w_{1n} and w_{2n} to form firm n's composite bid, $B_n = w_1 b_{1n} + w_2 b_{2n}$. From this it is easily seen that equilibrium bidding is governed by two factors. First, whether a firm wins or loses is solely determined by its composite bid, and, hence, we must identify the equilibrium composite bid (B^*_n) for each firm. Second, the individual components (b^*_{1n} and b^*_{2n}) of the equilibrium composite bids that maximize the payoff of each firm must be identified.

Generally, Nash equilibrium in an auction requires that no firm wishes to change its bids, given the bids placed by the other firms. Here, this reduces to specifying that winning firms do not wish to raise their bids and that losing firms could not lower their bids in order to become a profitable winner.[13] The firms submitting the two lowest composite bids "win" the process, and the individual bids placed by the winning firms are then used to calculate the prices in each market. We make the simplifying assumption that the price of a good is simply the average of the winning bids on that good.[14]

In deriving equilibrium bids, it will be useful to rank firms based on their costs of providing a "composite" good that consists of the individual goods supplied by winning firms. Specifically, the cost of providing this composite good is $(\hat{v}_{1,firm}/2)c_{1n} + (\hat{v}_{2,firm}/2)c_{2n} = (\gamma_1 c_{1n} + \gamma_2 c_{2n})(\hat{V}_{firm}/2)$. Denote (parenthetically) the firm with the lowest cost of providing the composite good as firm (1), the firm with the second lowest costs of providing the composite good as firm (2), and so on. More generally, let $MC_{(n)}$ represent firm n's cost of providing the

[11] The reader is referred to Hirshleifer and Riley (1992, chapter 10) for background on auction games with full information.

[12] While this assumption is simplistic, our results indicate that the pitfalls in the CMS design would only be exacerbated in a more complex environment.

[13] Clearly, a winning firm would not want to lower their bid as it would ONLY lower its profits since it was already winning.

[14] By eliminating the adjusted bid price from our model we are simplifying the trade-off faced by firms in choosing their optimal composite bid. It should be noted that by lowering their composite bid, firms in a CMS auction can increase their competitiveness ratio, thereby affecting prices in the entire category. However, this incentive still leads to bids that are skewed and not based on costs, and we use the simplified rule for ease of exposition.

composite good, let $b_{i(n)}$ represent firm (n)'s individual bid on good i, and let $B_{(n)}$ represent firm (n)'s composite bid.

In order to isolate the equilibrium composite bids, we first point out that a winning firm expects to earn $[\gamma_1(p_1 - c_{1n}) + \gamma_2(p_2 - c_{2n})](\hat{V}_{firm}/2)$, where p_i is the average of the winning bids on good i. It will be instructive to write these profits as $[(\gamma_1 p_1 + \gamma_2 p_2) - (\gamma_1 c_{1n} + \gamma_2 c_{2n})](\hat{V}_{firm}/2) = [(\gamma_1 p_1 + \gamma_2 p_2) - MC_n]\,(\hat{V}_{firm}/2)$. Clearly, a firm will not submit individual bids that result in equilibrium prices that give lower revenue than the firm's costs, MC. From this point of view, the CMS process is similar to a Bertrand pricing game in which firms' marginal costs are given by $MC_{(1)}$, $MC_{(2)}, \ldots,$ $MC_{(n)}$. Not surprisingly, equilibrium here requires a condition similar to that in the Bertrand game in that equilibrium bids must gravitate to a level at which revenues for the two most competitive firms would let the third most competitive firm break even, which is equivalent to the following condition

$$\frac{\hat{V}_{firm}}{2}\left[\gamma_1 \frac{b_{1(1)} + b_{2(2)}}{2} + \gamma_2 \frac{b_{2(1)} + b_{2(2)}}{2}\right] = MC_{(3)}. \tag{1}$$

At the same time, all other firms must bid aggressively above their MC using a mixing distribution, such that the marginal payoff of firms (1) and (2) from increasing one of their individual bids is outweighed by the chance that firm (3) would displace them as a winner.[15]

Like the Bertrand game, Equation 1 combined with other firms mixing aggressively above their MC is necessary for Nash equilibrium. However, unlike the Bertrand game, Equation 1 is not sufficient for Nash equilibrium here. The lack of sufficiency occurs because there are many combinations of individual bids by firms (1) and (2) that satisfy Equation 1, indicating that it is also necessary that firms choose their individual bids (b_{1n} and b_{2n}) optimally. The relation between Equation 1 and the optimality of the individual bids is best expressed by the following linear programming problem:

$$\begin{aligned} \min_{b_{1n}, b_{2n}} \quad & w_1 b_{1n} + w_2 b_{2n} \\ s.t. \quad & \frac{\hat{V}_{firm}}{2}\left[\gamma_1 \frac{b_{1(1)} + b_{2(2)}}{2} + \gamma_2 \frac{b_{2(1)} + b_{2(2)}}{2}\right] = MC_{(3)}. \end{aligned} \tag{2}$$

The Nash equilibrium caveat is that firms (1) and (2) must solve this problem simultaneously while the other firms mix aggressively above their MC.

The fact that the equilibrium conditions can be expressed as a linear programming problem with one constraint indicates that there are three possible outcomes. First, if the firm's estimate of relative demand for good 1, γ_1, is less optimistic than the CMS estimate w_1 (inferring that the firm's relative demand estimate for good 2, γ_2, is more optimistic than the CMS estimate w_2), then there is a corner solution in which $b_{1(n)} = 0$ and $b_{2(n)}$ is chosen so as to satisfy Equation 1. Second, if the firm's estimate of relative demand for good 2, γ_2, is less optimistic than the CMS estimate w_2 (inferring that its relative demand estimate for good 1, γ_1, is more optimistic than the CMS estimate w_1), then there is a corner solution in which $b_{2(n)} = 0$ and $b_{1(n)}$ is chosen so as to satisfy Equation 1. Finally, in the case in which the firm's estimates agree with CMS estimates, the choices of $b_{1(n)}$ and $b_{2(n)}$ are not unique, and any combination that satisfies Equation 1 is optimal.

[15] As the purpose of this section is to provide a heuristic view of equilibrium and not a formal proof, we do not derive these mixing distributions here. However, we do note that they exist and lead to the equilibrium bids by winning bidders mentioned in this section. The interested reader is referred to Hirshleifer and Riley (1992, chapter 10) for a discussion of mixing strategies in full information auctions.

Table 2. Marginal Cost Structure for Example 1

	A	B	C	D
c_{1n}	\$1.00	\$1.00	\$2.50	\$1.50
c_{2n}	\$1.00	\$3.00	\$1.00	\$1.50
$MC_n = 2[(1/2)c_{1n} + (1/2)c_{2n}]$	\$2.00	\$4.00	\$3.50	\$3.00

Several conclusions can be drawn from the equilibrium discussed above. First, because of the corner solutions, prices will not represent the actual costs of providing the goods, which was one of CMS's goals. Further, the resulting prices will be skewed depending on which goods had relative demand that was over/underestimated. Finally, it is possible that equilibrium bids will result in low cost providers being shut out of the market and relatively inefficient firms becoming Medicare providers. The following numerical examples highlight each of these problems with the current format and are aimed at providing a better understanding of the relationship between the optimality of the individual bids and Equation 1.

Example 1

Let there be four firms ($n = A, B, C, D$) competing for two positions as Medicare suppliers. Assume that these firms have the constant marginal costs presented in Table 2 and that both CMS and the firms believe that $v_1 = v_2 = 2$, resulting in weights of $w_1 = w_2 = \gamma_1 = \gamma_2 = 1/2$. Based on Table 2, firm C is (3) and $MC_{(3)} = \$3.50$. Since the firms' estimates match CMS estimates, it follows that composite bids of \$1.75 by firms A and D will result in revenues equal to \$3.50, which satisfies Equation 1 regardless of the specific individual bids placed by those two firms. Without regard to how firms A and D choose their individual bids, the outcome of the bidding process is inefficient, since firm D is not one of the two most efficient providers of either good, yet firm D wins. This inefficiency is most easily seen by comparing the outcome to that which would result if the prices of each good were determined under Bertrand competition. In that case, good 1 would be provided by firms A and B for a price of \$1.50 and good 2 would be provided by firms A and C for a price of \$1.50. Therefore, simply opening the market to pricing competition would not only lead to a situation in which the most efficient firms provide the goods, but it would also result in an overall reduction in expenditures of \$0.50 (\$3.00 vs. \$3.50).[16]

Since the firms' estimates match CMS's estimates in this example, any combinations of individual bids by firms (1) and (2) that lead to composite bids of \$1.75 are optimal. Thus, there is substantial variability in the expectation of prices, and very few of the possible outcomes will mirror prices being set according to the cost of providing the goods. While the variability of prices is not of consequence to the firms (since equilibrium requires that all combinations result in the same cost of providing the composite good), price variability will lead to transfers of consumer surplus such that one group of consumers subsidizes another. The next example shows that this type of subsidization is virtually guaranteed if CMS estimates do not match the firms' estimates.

[16] One could argue that the inefficiencies and price increases might be beneficial if the government could reduce transaction costs by limiting the number of suppliers and bundling the contracts. However, our communications with CMS indicated that price reductions were the primary objective and that significant savings in transactions costs were not expected.

Table 3. Marginal Cost Structure for Example 2

	A	B	C	D
c_{1n}	\$1.00	\$1.00	\$2.50	\$1.50
c_{2n}	\$1.00	\$3.00	\$1.00	\$1.50
$MC_n = 3[(2/3)c_{1n} + (1/3)c_{2n}]$	\$3.00	\$5.00	\$6.00	\$4.50

Example 2

Let the four firms from Example 1 have estimates of relative demand (γ_1 and γ_2) that differ from CMS's estimates. Rather than believing that there will be two units of each good demanded, the firms correctly believe that there will be four units of good 1 and two units of good 2 demanded, giving $\gamma_1 = 2/3$ and $\gamma_2 = 1/3$. Given its estimates (from Example 1) of $w_1 = w_2 = 1/2$, CMS will still be selecting two firms to supply the goods, and, for simplicity, we assume that each of the two winning firms will supply two units of good 1 and one unit of good 2 (i.e., the CMS estimates are incorrect). All other information is known to the firms, including the constant marginal costs given in Table 3. The firms' marginal costs of supplying the "composite good" (two units of good 1 and one unit of good 2) are therefore \$3.00, \$5.00, \$6.00, and \$4.50, respectively.

Equation 1 requires that firms A and D choose individual bids that result in prices such that if they win, the revenue from supplying the composite good is \$5.00 [$= MC_{(3)}$]. In order to investigate the importance of choosing the individual bids optimally, assume for the moment that firms A and D ignore the corner solution and bid $b_{1A} = b_{1D} = \$1.00$ and $b_{2A} = b_{2D} = \$3.00$ (which, incidentally, are firm B's marginal costs). These bids result in composite bids of \$2.50, which, if they win, yield prices $p_1 = \$1.00$ and $p_2 = \$3.00$ and a cost of supplying the composite good of 2(\$1.00) + 1(\$3.00) = \$5.00, thus satisfying Equation 1. However, since these individual bids were not chosen optimally, they will not result in firms A and D winning. To see this, consider the result if firms B and C bid $b_{1B} = b_{1C} = \$4.00$ and $b_{2B} = b_{2C} = \$0.00$. These bids would result in composite bids of 1/2(\$4.00) + 1/2(\$0.00) = \$2.00, which would defeat the composite bids of \$2.50 made by firms A and D. At the same time, the resulting prices $p_1 = \$4.00$ and $p_2 = \$0.00$ result in revenues from supplying the composite good of \$8.00, which is profitable for both firms B and C, since their costs of supplying the composite good are \$5.00 and \$6.00, respectively. In other words, despite the fact that their bids satisfied Equation 1, by not choosing their individual bids optimally, firms A and D opened the door for firms B and C to game the system and win the process.

To see that adhering to the corner solution shuts firms B and C out of the market, consider the result when firms A and D optimally bid $b_{1A} = b_{1D} = \$2.50$ and $b_{2A} = b_{2D} = \$0.00$. By submitting these bids, firms A and B generate composite bids of 1/2(\$2.50) + 1/2(\$0.00) = \$1.25 and sets prices $p_1 = \$2.50$ and $p_2 = \$0.00$. At these prices, firm B would make zero profit even if it won, and firm C would lose money. Hence, neither firm B nor firm C can profitably submit a lower composite bid (as doing so would earn them negative profits), and the equilibrium consists of highly skewed prices.

Finally, consider what happens when firms A and D follow the strategy prescribed by CMS of bidding their costs. In this case, such a strategy results in bids $b_{1A} = \$1.00$, $b_{1D} = \$1.50$, $b_{2A} = \$1.00$, $b_{2D} = \$1.50$. The resulting composite bids are $B_A = \$1.00$ and $B_D = \$1.50$, yielding prices $p_1 = \$1.25$ and $p_2 = \$1.25$, which generate revenue of supplying the composite good of \$3.75. While this shuts firms B and C out of the market and is profitable for firms A

and D, it is clear from the above explanation that this result is suboptimal, since the corner solution bids, $b_{1A} = b_{1D} = \$2.50$ and $b_{2A} = b_{2D} = \$0.00$, generated revenues of \$5.00. The reason that bidding one's costs is not an equilibrium strategy is that it does not satisfy Equation 1 with equality and thus leaves money on the table.

The fact that demand in this model is perfectly inelastic implies that skewed prices simply transfer consumer surplus and may not be alarming from certain policy perspectives. However, since different consumers may be buying the different goods, we anticipate that high price increases on some goods will lead to protests by consumers of those goods. All in all, the CMS bidding process clearly does not elicit the intended truthful bidding of costs and can lead to strategic skewing of bids if firm estimates of demand are not aligned with the CMS estimates. The next section extends these instructive examples and shows that they are robust in a world of incomplete information.

4. Incomplete Information

We now show that the predictions from the previous section are valid in an incomplete information environment. In this model, there are N risk-neutral firms competing for the right to supply a product category containing i (=1, 2) distinct goods. Firm n (=1,…, N) has constant marginal cost c_{in} of providing good i. CMS has determined that M suppliers are necessary to provide the entire product category. As in the previous section, we impose a simplified version of the rule for calculating reimbursement prices on each good. Once again, it is the average of the winning individual bids on that good.

Each firm submits bids b_{1n} and b_{2n}, and their composite bids ($B_n = w_1 b_{1n} + w_2 b_{2n}$) are calculated using the CMS weights (w_1 and w_2). In formulating a firm's expected payoff function, we once again allow for the possibility that firm n has its own (exogenous) forecasts of the relative demands (γ_{1n} and γ_{2n}). Since firms are assumed to be risk neutral, γ_{in} will enter the profit function linearly and can be viewed as either the true value of demand or an expectation.

It follows that firm n's objective function can be written as

$$\int_{B_n}^{B_U} [\gamma_{1n}(p_1(b_{1n},x) - c_1) + \gamma_{2n}(p_2(b_{2n},x) - c_2)] f(x)\, dx, \tag{3}$$

where the integral is taken over events in which firm n wins, where $f(x)$ is the (continuous) density function of the Mth lowest of the firm's opponents' composite bids,[17] where B_U is the highest composite bid that any firm will place, and where $p_i(b_{in},x) = \Sigma^{M}_{j=1} E(b_{ij}|x)/M$. The firm's trade-offs in this problem are twofold. First, the firm must target a specific composite bid that weighs the fact that a lower composite bid is more likely to win with the fact that placing a lower composite bid requires lowering the individual bid on a good, thus lowering the profit margin on that good if the firm wins. On the other hand, while increasing an individual bid will increase profitability on that good, it also increases the composite bid, making it less likely that the firm will win.

[17] We focus on the Mth lowest of the opponents' composite bids because if the optimizer submits a lower composite bid, it will be a winner.

Maximizing Equation 3 with respect to b_{1n} and b_{2n} yields the following first-order conditions:

$$\frac{\gamma_{1n}}{M}[1 - F(B_n)] - w_1[\gamma_{1n}(p_1[b_{1n},B_n] - c_{1n}) + \gamma_{2n}(p_2[b_{2n},B_n] - c_{2n})]f(B_n) = 0,$$
$$\frac{\gamma_{2n}}{M}[1 - F(B_n)] - w_2[\gamma_{1n}(p_1[b_{1n},B_n] - c_{1n}) + \gamma_{2n}(p_2[b_{2n},B_n] - c_{2n})]f(B_n) = 0$$

where $F(x)$ is the distribution function corresponding to $f(x)$. Taking the ratio of first-order equations gives the simple relation

$$\frac{\gamma_{1n}}{\gamma_{2n}} = \frac{w_1}{w_2}. \quad (4)$$

Equation 4 provides several enlightening characteristics of equilibrium bidding. First, if a firm's demand estimates are in agreement with the CMS estimates, any combination of individual bids that leads to the firm's optimal composite bid is equally good, as in Example 1. Alternatively, if a firm's estimates do not align with CMS's estimates, Equation 4 cannot hold, and there is no interior solution. The theoretical result is that the bid on the good for which CMS estimates of relative demand are too optimistic would be zero, while the entirety of the composite bid would be placed on the good for which CMS estimates are overly pessimistic, as in Example 2.

The intuition behind this last fact is simple. If $\gamma_{1n} < w_1$, then the firm expects lower relative demand on good 1 than the CMS estimates indicate. Thus, the importance of the individual bid on good 1 is being overstated. Hence, by lowering its bid on good 1, the firm can increase its bid on good 2, all the while maintaining the optimal composite bid. While this means that it will be accepting a lower price for good 1, it expects that the reduction in profits will be more than offset by the increase in profits caused by the increase in the price of good 2. Notice that a firm is even willing to take a loss on good 1, as it expects to be more than compensated by the additional profits generated on good 2. Practically, bids in the CMS process would not be lowered to zero because of the CMS rule that bids can not be below the wholesale price of the good.[8] Thus, the relevant corner solution here calls for bids equal to wholesale prices on the goods for which CMS overestimated relative demand.

5. Data

The preceding models have not only shown that the current rules of the CMS bidding process are suboptimal, they also provide us with predictions about bidding behavior and the resulting prices under these rules. It is these testable predictions that are the focus of this section. Before turning to the data, we offer a few comments concerning the limitations placed on empirical testing by the aggregation rules.

In our opinion, the most appropriate test of our theoretical predictions would involve the structural estimation of the stochastic properties of a firm's costs and how they relate to bids. However, we have seen that in equilibrium, the individual components of the composite bid may not matter, and even if they do, they depend on both the firm's costs and its forecasts of demand. It follows that there is no way to retrieve the individual marginal costs from individual bids. To compound this problem, CMS has not made the composite or individual bid information available. Hence, using structural econometrics to estimate the underlying distribution of costs is not possible. Yet there is a wealth of information available on the CMS Website that can be utilized.[18] While the site is intended to provide suppliers and beneficiaries who are involved in the projects with information, it also provides us with a minimum amount of data that can be used to test our theoretical predictions. Specifically, the Website includes data from all three of the completed DMEPOS Competitive Bidding Demonstration Projects, including detailed demand information on each location for one year prior to the bidding stage of the project, a list of winning suppliers, and the old and new fee schedules.

The Polk County Round I data tell us that CMS received 73 composite bids from 30 different firms for the five product categories included in the project. These categories are as follows: enteral nutrition equipment (enterals), urological supplies (urologicals), surgical dressings, hospital beds and accessories (hospital beds), and oxygen supplies (oxygen). The top portion of Table 4A shows that 15 of the 30 bidding firms won the right to supply and how they were distributed across the categories. Anywhere from four to 13 firms were chosen as providers for product categories. Surgical dressings and urologicals have the smallest number of suppliers, four and five, respectively, while hospital beds and oxygen have the greatest number of suppliers with 10 and 13, respectively.

The lower portion of Table 4A describes the supplier situation for Polk County Round II.[19] This project had 17 independent firms win the bidding process. Of these 17 firms, eight were suppliers of hospital beds, 10 supplied oxygen, only four supplied surgical dressings, and six supplied urologicals. Only one of the 17 suppliers had responsibility for all categories, eight were suppliers of two categories, and another seven supplied only one category. Additionally, any firm responsible for surgical dressings supplied at least one other category.

The winning firms and the categories that they supply for the San Antonio project are listed in Table 4B. The San Antonio project received 179 composite bids from 70 different firms for the five product categories included in the project. These categories are as follows: hospital beds and accessories (hospital beds), nebulizer inhalant drugs (nebulizer drugs), non-customized orthotics (orthotics), oxygen supplies (oxygen), and manual wheelchairs (wheelchairs). Of the 70 firms, 51 won the right to be Medicare DMEPOS suppliers in San Antonio. Anywhere from 10 to 29 firms were chosen as Medicare providers for the various product categories. Orthotics and nebulizer drugs have the smallest number of suppliers, 10 and 11, respectively, while hospital beds and oxygen have the greatest number of suppliers, with 24 and 29 suppliers, respectively.

In order to investigate the impact of the bidding process on prices in each project, we begin by comparing the prices that resulted from the bidding process to the prices specified by the fee schedule prior to the project. Tables 5–8 show the results of our analysis. In Polk County Round I the average price decrease for all goods across all categories is remarkably small, 4.46%, compared to the expectation of significant savings.[20] Table 6 shows that the San Antonio project experienced a much higher average price decrease of 15.37%, while Polk County Round II showed improvement compared to Polk County Round I, with an average price decrease of 8.57%. Finally, over all of the projects the average price change, as illustrated

[18] As of December 2006, the Website is http://www.cms.hhs.gov/DemoProjectsEvalRpts/MD/list.asp.

[19] Recall that Polk County Round II did not include the enterals category.

[20] Hoerger, Finkelstein, and Bernard (2001) report a much better result (a 17% average price decline) for the Polk County Round I project. Unfortunately, this level of savings is misleading in that it only uses goods on which the prices actually fell in the calculation, thereby avoiding the basic tenant of our paper: that the price decreases on some goods were only made possible by increases in the prices of other goods.

Table 4A. Demonstration Suppliers by Product Category, Polk County Round I (PCI) and Round II (PCII)

Polk County Round I					
Company	Enterals	Urologicals	Surgical Dressing	Hospital Beds	Oxygen Supplies
PCI-A	X			X	X
PCI-B	X	X	X	X	X
PCI-C					X
PCI-D	X			X	X
PCI-E	X			X	X
PCI-F	X			X	X
PCI-G					X
PCI-H				X	X
PCI-I		X	X		X
PCI-J			X		
PCI-K	X	X		X	X
PCI-L	X	X	X		
PCI-M				X	X
PCI-N		X		X	X
PCI-O				X	X
Total = 15	7	5	4	10	13

Polk County Round II					
Company	Enterals	Urologicals	Surgical Dressing	Hospital Beds	Oxygen Supplies
PCII-A	—			X	
PCII-B	—			X	X
PCII-C	—			X	X
PCII-D	—				X
PCII-E	—	X			
PCII-F	—	X			
PCII-G	—			X	X
PCII-H	—	X	X		
PCII-I	—	X	X		
PCII-J	—				X
PCII-K	—			X	X
PCII-L	—	X	X	X	X
PCII-M	—	X	X		
PCII-N	—			X	
PCII-O	—				X
PCII-P	—				X
PCII-Q	—			X	X
Total = 17		6	4	8	10

by Table 8, was a decline of only 9.22%, which most likely did not meet CMS's expectations of *significant* price reductions, since all of these calculations are relative to the outdated, inflated fee schedule.

Another result of interest is that the variation in the percentage change in price is quite large, with maximum price decreases of 70.07% for Polk County Round I, 34.69% for San Antonio, and 38.45% for Polk County Round II, compared to minimum price decreases (in other words, maximum price increases) of −458.65% for Polk County Round I, −100.00% for San Antonio, and −162.17% for Polk County Round II. Of the 162 goods involved in the Polk County Round I project, 50 actually experienced price increases, while 11 of the 162 goods in

Table 4B. Demonstration Suppliers for San Antonio (SA)

San Antonio					
Company	Hospital Beds	Nebulizer Inhalation Drugs	Orthotics	Oxygen	Manual Wheelchairs
SA-A	X			X	
SA-B	X				
SA-C				X	
SA-D				X	
SA-E	X	X		X	X
SA-F				X	X
SA-G	X				
SA-H	X			X	X
SA-I		X		X	X
SA-J	X	X		X	X
SA-K		X		X	
SA-L	X				X
SA-M				X	
SA-N		X			
SA-O	X			X	X
SA-P	X				X
SA-Q			X		
SA-R				X	
SA-S				X	
SA-T		X			
SA-U			X	X	
SA-V	X		X		X
SA-W	X		X		X
SA-Y		X			
SA-Z		X			
SA-AA	X			X	
SA-AB				X	
SA-AC		X			
SA-AD			X		
SA-AE	X			X	X
SA-AF	X				
SA-AG				X	X
SA-AH				X	
SA-AI				X	
SA-AJ			X		
SA-AK	X	X		X	X
SA-AL				X	X
SA-AM	X				
SA-AN	X			X	X
SA-AO	X	X			X
SA-AP				X	
SA-AQ			X		
SA-AR			X		
SA-AS	X			X	X
SA-AT	X		X	X	X
SA-AU	X			X	X
SA-AV	X			X	X
SA-AW				X	
SA-AX			X		
SA-AY	X				X
SA-AZ	X				X
Total = 51	24	10	11	29	22

Table 5. Average Price Decreases, Polk County Round I

Category	Average Price Decrease (%)	Minimum (%)	Maximum (%)
Enterals	16.89	−81.99	70.07
Hospital beds and accessories	25.58	−4.26	40.36
Oxygen supplies	16.86	6.79	32.39
Surgical dressings and supplies	−20.33	−73.88	27.00
Urologicals	8.20	−458.65	31.01
Overall	4.46	−458.65	70.07

the San Antonio project experienced no change in price or a price increase, and 13 of the 76 goods in Polk County Round II experienced price increases, much like our theoretical models predicted.[21]

To take our analysis further, we tested our prediction that goods with relative demands that are perceived by the firms to be underestimated by CMS (weights that are too low) would experience price increases. This price increase would result from the fact that a firm would increase (decrease) its bid on goods for which CMS underestimated (overestimated) relative demand. Hence, this would inflate (deflate) the resulting prices on goods for which firms had relative demand estimates that exceeded (fell short of) those of CMS. We were able to do this by comparing the weights given to the 130 individual goods that appeared in both Polk County Rounds I and II. Recall that the weights given to the goods in Polk County Round I were based on the estimated relative demand for the goods during the experiment. Conveniently, the estimated demand weights given to the goods in Polk County Round II were based on the demand realizations during Polk County Round I. Hence, if the weights from Polk County Round I exceeded (fell short of) the weights from Polk County Round II, this was a sign of overestimation (underestimation). Therefore, we created an indicator variable to determine if the relative demand for a good was underestimated.[22] Underestimation occurred for 20% of the goods (25 goods) that appeared in both Rounds I and II in Polk County. Using this indicator variable, we then checked for a correlation between price increases and relative demand underestimation. We found that if a good's relative demand was underestimated by CMS in Round I, this significantly increased the probability that the good would experience a price increase as a result of the bidding process. In fact, we found that underestimation increases the probability that a good experienced a price increase by 25 percentage points. Specifically, goods with underestimated relative demand experienced an average increase of $3.95 per unit.

[21] In addition, we calculated a pairwise *t*-test and found that we could reject the hypothesis that the old fee schedule and the demonstration prices were equal.

[22] Demand realizations were not available for Polk County Round II or San Antonio. Hence, a similar variable could not be constructed for those rounds.

Table 6. Average Price Decreases, San Antonio Area

Category	Average Price Decrease (%)	Minimum (%)	Maximum (%)
Hospital beds and accessories	22.62	14.22	29.61
Nebulizer inhalants	−10.66	−100.00	34.69
Non-customized orthotics	20.75	3.00	28.76
Oxygen supplies	17.33	6.29	29.75
Manual wheelchairs	20.38	3.78	28.57
Overall	15.37	−100.00	34.69

Table 7. Average Price Decreases, Polk County Round II

Category	Average Price Decrease (%)	Minimum (%)	Maximum (%)
Enterals	N/A	N/A	N/A
Hospital beds and accessories	31.29	21.66	38.45
Oxygen supplies	17.54	12.11	23.43
Surgical dressings and supplies	2.43	−80.00	17.84
Urologicals	−2.97	−162.17	33.79
Overall	8.57	−162.17	38.45

N/A indicates not applicable.

Other implications of our model include the possibility of diminished quality of service. First, the fact that a firm wishing to supply a good was "forced" to supply every other good in that category may result in the firm trying to avoid those goods in the category that are not cost effective. Second, as firms game the system, some goods will be under-priced and, hence, winning firms will be hesitant to supply those goods if the price ends up being too low.

Currently, there is no information pertaining to service quality levels. However, there is anecdotal evidence of diminished quality that comes from CMS itself. For instance, in an effort to minimize the negative impact of declines in service quality, quality check site visits of all winning firms have been instituted. In addition, an independent contractor has been assigned to conduct quality assurance surveys of the beneficiaries involved in the competitive bidding experiment. Both efforts on CMS's behalf seem to indicate that CMS believes that the possibility of a decline in quality is great enough to warrant costly checks on both the firm and beneficiary sides of the market. Further problems with the process are evidenced by the fact that some winning firms have attempted to withdraw from the program.

6. Conclusion

The theoretical results found in this paper show that the CMS format will likely result in an inefficient supply of medical equipment, increased prices on a number of goods, and

Table 8. Average Price Decreases, All Sites, All Rounds

Category	Average Price Decrease (%)	Minimum (%)	Maximum (%)
All Sites, All Rounds			
Hospital beds and accessories	26.56	−4.26	40.36
Oxygen supplies	17.51	6.29	32.39
Round I Polk County & Round II Polk County			
Surgical dressings and supplies	−12.63	−80.00	27.00
Urologicals	4.01	−458.65	33.79
Only San Antonio			
Nebulizer drugs	−10.66	−100.00	34.69
Orthotics	20.75	3.00	28.76
Manual wheelchairs	20.38	3.78	28.57
Only Round I Polk County			
Enterals	16.89	−81.99	70.07
Overall	9.22	−458.65	70.07

potential problems for beneficiaries in obtaining equipment. Using preliminary results from actual CMS Demonstration Projects, empirical evidence is provided that supports these predictions. While we applaud CMS's attempts to reduce medical expenditures and its initiative of implementing competitive bidding as a means to this end, we strongly urge a restructuring of the bidding process.

The problem with the CMS process is that the bid scoring and price formulation procedures are inconsistent with the bidding behavior that CMS wishes to induce. That is, overly complex rules for choosing winners and setting prices distort the incentives that bidders face and may actually result in increased prices for some consumers. We believe that the misalignment of the rules with the desired bidding behavior stems from a faulty application of single-unit auction results to a multi-unit setting: a misconception that has even been propagated by Nobel Laureates (see Ausubel and Cramton 2002, pp. 1, 27, for a discussion).

In conclusion, it appears that the initial formulation of the competitive bidding process fails to achieve CMS's goals. However, by initiating competitive bidding in an experimental manner, CMS has allowed for in-depth analysis of its bidding process before whole-scale changes are set in motion. We end by noting that the emerging literature on multi-unit auctions provides a host of alternative bidding formats that do not suffer from the problems identified in this paper (see Cramton, Shoham, and Steinberg 2006). Our suggestion is that CMS develop a descending variant of Ausubel, Cramton, and Milgrom's (2006) clock-proxy auction. In that auction, a first stage of open bidding allows for simple transparent price discovery, while a second round of proxy bidding ensures efficiency. This format is particularly promising, as it eliminates the exposure problem, eliminates the incentives for demand reduction, and mitigates collusion, all *without* distorting bidder incentives, thus increasing the expectation of reduced Medicare prices.[23]

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[23] For more details, the interested reader is referred to Chapter 5 of Cramton, Shoham, and Steinberg (2006).

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