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SOLE-SOURCING VERSUS COMPETITIVE BIDDING: US GOVERNMENT AGENCIES' PROCEDURAL CHOICES FOR MAINFRAME COMPUTER PROCUREMENT*

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Why do government agencies sole-source sometimes and use competitive procedures for procurement other times? This paper develops a testable model of the economic determinants of agencies' procurement procedures and applies it to procurement of general purpose mainframe computer systems. Factors related to the extent of vendor competition or the value of a procurement importantly influences an agency's procedural choice. Extensive experience between an agency buyer and an incumbent vendor, or the buyer's experience with IBM, also helps predict the agency's procedural choice.

I. INTRODUCTION

THE PROCUREMENT processes of US government agencies employ either competitive procedures or sole-sourcing. Competitive bidding involves the solicitation of multiple bids; in sole-sourcing, agencies by-pass the solicitation of competitive bids and instead designate a single vendor as a "sole-supplier". The first question that federal agencies routinely face for non-labor purchases is whether or not to sole-source. Why is sole-sourcing employed sometimes and competitive procedures used other times? Little empirical research has addressed this issue.

This paper proposes a simple approach for measuring the determinants of an agency's procedural choice. The approach is tailored to the acquisition of a general purpose mainframe computer, which is a commercially standardized product. The winning vendor and the agency's procurement history are observed, but little else is. The method employed measures the importance of three economic factors: (1) the agency's previous computer use, (2) the character of the computer needed, and (3) the state of vendor potential supply.

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The results of this study show that several economic factors contribute to an agency's procedural choice. The extent of potential vendor competition in a market niche and the fixed costs to vendors of bidding are usually important determinants. The size of the incumbent's installed base also matters; yet this effect is surprisingly weak compared with other economic factors. In addition, agencies that previously used IBM's systems are more likely to engage in competitive procurement. Different interpretations and implications are discussed in the text.

Until recently computer procurement was difficult to analyze. Acquisition data were aggregated over many years and many agencies, and individual acquisitions were difficult to observe. Analysis is now possible because of the creation of a sample of observations of commercial mainframe computer acquisitions by the offices of federal agencies from 1972 to 1983 (Greenstein [1989]).

II. THE ECONOMIC APPROACH TO PROCUREMENT PROCEDURES

There exists no general model of the determinants of an agency's procedural choice. Almost all bidding models ignore the procedural decision and focus on vendor bidding in a competitive situation (e.g. McAfee and McMillan [1987], Marshall et al. [1994a, 1994b]). The closest related models are those of second-sourcing: e.g., government policies for purchasing from more than one vendor (Anton and Yao [1987], Demski et al. [1987]). These are also inappropriate here because they focus on the use of second-sourcing when idiosyncratic products imply production learning curves, as in military weapons procurement. In contrast, this paper's focus is on mainframe computers, which are standardized commercial products.

This paper's empirical approach presumes that the anticipated number of bidders in a competitive bidding situation largely decides an agency's procedural choice.[1] This approach explains observed activity, which is illustrated in Figure 1. After securing funding for an acquisition, the agency chooses whether or not to sole-source; this decision is observed by the econometrician. The agency makes this decision based on the anticipated number of vendors in competitive procurement, which is not observed. If the agency expects one vendor to bid, then it sole-sources with that vendor, which is observed. If the agency anticipates more than one vendor, then it employs competitive procedures, and competitive bidding (i.e., usually

[1] This is consistent with long-standing government policy to use sole-sourcing when only one vendor possesses a "unique capability" that cannot be easily duplicated; that is, when only one vendor would bid in a competitive procurement. For more on government rules regarding procurement prior to the passage of the Competition in Contracting Act [1984], see NBS [1983] or Petrillo [1982]. See Greenstein [1989] for a description of the institutional factors that underlie this paper's model of procedural choice.

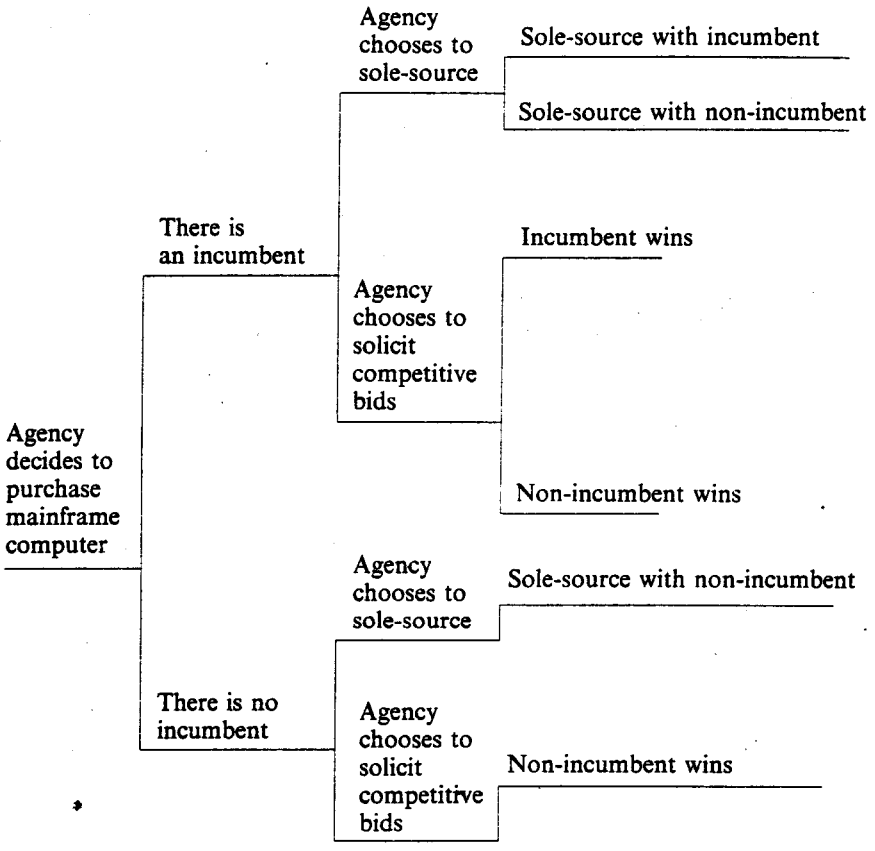

FIGURE 1
THE SEQUENCE OF OBSERVED EVENTS

first-price, sealed-bid) decides the winning vendor, who is observed. The econometrician never observes the anticipated number of bidders, nor the number that do bid and lose in a competitive procurement. This paper's approach assumes that agencies make reasonable forecasts—i.e., that the anticipated and actual number of bidders are usually close.

This approach is in the spirit of Bresnahan and Reiss [1991] or Reiss and Spiller [1990]. The agency's procedural choice depends on its anticipation of vendor's bidding behaviour (or entry decisions), which is not observed. If agencies can forecast vendors' bidding behaviour, the economic factors deciding the anticipated (and actual) number of bidders will influence the choice of procedures. This paper may be seen as a test of this economic approach.

When there is a single incumbent vendor, four economic factors decide bidding outcomes. These are: 1. $\Phi(f_{INC})$, the probability that the incumbent will bid, where $f_{INC} = X\Theta$. X describes factors influencing the profitability of

bidding, and Θ are the weights placed on these factors by incumbents; these weights are known to agencies, but must be estimated by the econometrician. 2. $\Phi(f_{NONINC1})$, the probability that at least one non-incumbent vendor will bid against an incumbent, conditional on the incumbent's bidding, where $f_{NONINC1} = X\alpha$; here, X are the same set of factors and α are a different set of weights. 3. $\Phi(f_{NONINC2})$, the probability that two or more non-incumbents will bid against another, conditional on the incumbent's not bidding, where $f_{NONINC2} = X\beta$; X and β have obvious interpretations. 4. $\Phi(\Gamma)$, the probability that the incumbent will win a competitive bid against a non-incumbent, where Γ is estimated.

Under this paper's approach, the probability that the agency (buyer) sole sources with the incumbent is the same as the probability that the incumbent is the sole bidder. If events are independent and a single incumbent commits first, it is easy to see that this probability is $\Phi(f_{INC})[1 - \Phi(f_{NONINC1})]$. Under similar assumptions, the probability that the buyer sole-sources with a non-incumbent is the same as the probability that only one non-incumbent bids after the incumbent does not, which is just $[1 - \Phi(f_{INC})][1 - \Phi(f_{NONINC2})]$. The probability that an incumbent wins a positive bidding situation is $\Phi(f_{INC})\Phi(f_{NONINC1})\Phi(\Gamma)$. The probability that a non-incumbent wins a competitive bidding situation is the sum of the probability that the incumbent loses to the non-incumbent, which is $\Phi(f_{INC})\Phi(f_{NONINC1})[1 - \Phi(\Gamma)]$, plus the probability that two non-incumbents bid against one another and not an incumbent, which is $[1 - \Phi(f_{INC})]\Phi(f_{NONINC2})$.

The estimating equation for procedural choice follows from the above model.[2] When the errors are uncorrelated, the log-likelihood function for each observed acquisition is

$$
\begin{aligned}
&Y_{SSI} * \log\{\Phi(f_{INC})[1 - \Phi(f_{NONINC1})]\} \\
&+ Y_{SSNI} * \log\{[1 - \Phi(f_{INC})][1 - \Phi(f_{NONINC2})]\} \\
&+ Y_{COMPI} * \log\{\Phi(f_{INC})\Phi(f_{NONINC1})\Phi(\Gamma)\} \\
&+ Y_{COMPNI} * \log\{\Phi(f_{INC})\Phi(f_{NONINC1})[1 - \Phi(\Gamma)] \\
&+ [1 - \Phi(f_{INC})]\Phi(f_{NONINC2})\},
\end{aligned}
$$

where Y_{SSI}, Y_{SSNI}, Y_{COMPI}, and Y_{COMPNI} are zero-one indicator variables for each of the possible four outcomes: 1. Sole-sourcing with an incumbent vendor; 2. Sole-sourcing with a non-incumbent; 3. Competitive procedures won by an incumbent; 4. Competitive procedures won by a non-incumbent. Fitting this log-likelihood to observed data will generate estimates of Θ, α,

[2] This correspondence presumes that every procurement elicits at least one bidder, which is plausible. It is extremely rare to observe otherwise. Nonetheless, to be strict, all inferences are conditional on observing at least one bidder.

β, and Γ. This framework easily generalizes to a case where there is no incumbent[3] and to a case where the errors are correlated.[4]

The above log-likelihood is superior to a single probit of sole-sourcing versus competition. First, the above model distiguishes between sole-sourcing with an incumbent vendor and with a non-incumbent, while a single probit would not. If an agency becomes "locked-in" to an incumbent, this "lock-in" positively influences sole-sourcing with the incumbent, but negatively influences sole-sourcing with a non-incumbent. Second, the above log-likelihood accounts for the effects of "lock-in" on competitive outcomes, while a simple probit would not. If an agency favors an incumbent, this favoritism positively influences the probability that an incumbent eventually bids and wins a competitive bid. In contrast, it negatively influences the probability that some non-incumbent bids and wins a competitive bid.[5] Both differences are important because other evidence (Greenstein [1991, 1993b]) suggests that buyers do become "locked-in" to incumbent vendors. Finally, as shown in Greenstein [1989], all results from a probit are subsumed as special cases to the results from the above log-likelihood.

III. DATA

General Services Administration (GSA) surveys provide consistent information about the installed computers at every non-classified government installation, including military installations, between 1972 and 1983.[6] Computer tapes of the original surveys are the source on whether an agency employed sole-sourcing or competitive procedures. The paper restricts attention to the 221 acquisitions of commercial general purpose mainframe computers[7] that occurred at sites having no more than one incumbent vendor. This restriction reduces the modeling difficulties, as noted above. As a secondary benefit, it eliminates several unusual computer users within the Department of Defense and the Department of Energy. Summary statistics of the means, standard

[3] The sample includes instances in which there was no incumbent, with either sole-sourcing or competitive bidding following. In these cases, only $f_{NONINC2}$ is estimated, since $\Phi(f_{NONINC2})$ measures the probability that more than one non-incumbent bids. Coefficient estimates did not substantively change when these observations are excluded. Including them improves the precision of the estimates in $f_{NONINC2}$.

[4] In the case of correlated errors, the correlation between the error in $f_{NONINC1}$ and $f_{NONINC2}$ is not identified. So only two additional parameters are estimated.

[5] The above can also be made consistent with many bidding models of procurement, which aids in selecting regressors and interpreting results. Greenstein [1989] explores this topic.

[6] I would like to thank Martha Mulford Gray of NIST, Frank Fisher, and the IBM corporation for help in locating the last existing copy of this dataset. See NBS [1977, 1979, 1981, 1982], and GSA [1972–1982] for compilations. See Greenstein [1989] for details.

[7] A "commercial" system is any system listed in IDC's EDP *Industry Report* census of the mainframe industry or in Phister's [1979] census of the industry. Only acquisitions that included all relevant information were included. See Greenstein [1989].

TABLE I
SUMMARY STATISTICS FOR EXOGENOUS VARIABLES

Abbreviation	*Mean*	*STD DEV*	*Minimum*	*Maximum*
COMPSYS	33.66	10.05	13.00	74.00
INCUMBSYS	5.68	3.55	0.00	19.00
DEDAP	0.12	0.32	0.00	1.00
SIZE	4.85	1.35	2.0	7.00
NETWORK	4.98	6.23	1.00	34.00
NOINCUMBENT	0.12	0.32	0.00	1.00
INVEST	1.22	2.75	0.0	25.30
EXPERIENCE	3.43	2.54	0.00	11.50
EXPERIENCE2	18.27	22.41	0.00	132.25
CAPACITY	10.88	20.70	0.00	118.87
IBMINC	0.39	0.49	0.00	1.00

Note: For definitions, see text.

deviations, minima, and maxima are included in Table I. The data appendix to Greenstein [1989] includes more detail. The discussion below summarizes the set of exogenous variables.

Agencies anticipate whether their incumbent vendor and any non-incumbents will bid. Therefore, the model should include measures of the ease with which vendors can supply computers. These measures are divided between those for an incumbent, X_{SUPINC}, and those for non-incumbents, $X_{SUPNONINC}$. International Data Corporation's (IDC) survey of the commercial market each quarter provides a complete record of what an agency could anticipate from each potential vendor in every market segment.[8] The number of systems offered by non-incumbents in the market segment of the purchase is called COMPSYS in Table I. It comprises $X_{SUPNONINC}$. A count of the number of systems offered by the incumbent in the market segment is called INCUMBSYS. It comprises X_{SUPINC}.

Agencies know that special or broad requirements can influence the anticipated costs to bidding for both incumbent and non-incumbent. Special requirements raise costs and standard requirements lower costs. These factors are labelled as $X_{SPECIAL}$ and are related to the chracteristics of the system specifications requested by the agency.[9] DEDAP is a dummy variable showing whether a system is for a dedicated application; a dedicated

[8] This assumes that exogeneity of the market segment will be warranted by the breadth of the IDC segments and the government system labels employed. Market segments largely varied by computing power. See International Data Corporation, EDP *Industry Reports*.

[9] Several other variables were tried in earlier specifications, but all were found to be less informative. These included measures of the technical age of the system acquired, indicators of whether the acquired system was multi-processor, and whether it was acquired for a DOD subagency such as the Army, Air Force, or Navy. Year of acquisition was also found to be uniformative. The remaining variables comprise a minimal list.

application is likely to be less attractive to a potential vendor and will decrease the probability of eliciting much bidding. SIZE proxies for the value of the acquisition requested; if the fixed costs of bidding deter vendors from bidding, then the larger the value of the procurement, the more likely that more vendors will bid. SIZE is constructed from the IDC survey of the commercial market. IDC classifies each system by size 2, 3, 4, 5, 6, or 7, which is highly correlated with the system price.[10] NETWORK measures the number of acquisitions at organizationally-related offices in the same agency in the same year; this should proxy for the links between contracts at different offices within the same administrative unit as this agency, partly measuring how vendor bidding at one site influences acquisitions at related sites.[11] Finally, NOINCUMBENT is a dummy variable that only appears when there is no incumbent and only in $f_{NONINC2}$; it corrects for any change in non-incumbent vendor behavior when there is an incumbent (compared with when there is none).

The presence when there is an incumbent vendor is likely to affect a buyer's choices. For example, the greater are the previous purchases, the greater is the likelihood that the incumbent vendor has a system that suits the buyer's needs. In addition, the greater is a user's commitment to an existing stock of equipment, the greater potential difficulty the user faces when replacing old equipment with new equipment from a producer of incompatible equipment. All potential vendors know about a buyer's previous investment and bid accordingly (or do not bid at all).

Several variables address this factor. A vector measuring installed base is labeled $X_{INSTALLED}$. INVEST is the recorded value (in millions of dollars) of the owned equipment on site, adjusted for changing producer prices (1967 = 100); it should proxy for the value of switching costs embedded in all equipment, and it is particularly good at identifying the agency sites that have extensive investments in miscellaneous peripheral equipment (as compared with CAPACITY, defined below). EXPERIENCE equals the average age (in years) of the systems that a buyer already possesses; a squared term (EXPERIENCE2) is included because the value of experience should depreciate rapidly after systems become especially old. CAPACITY approximates the total computing capacity on site; it is the sum of the IDC SIZE ratings for all mainframe systems at a site; the larger is the capacity of the site, the greater is the

[10] The importance of fixed costs and the size of the procurement may be more important in federal procurement compared with private industry. When the Government Accounting Office [1981] compared private practices with federal procurement practices, they observed that computer vendors needed to meet more requirements to qualify for federal bidding than did those selling to private industry.

[11] There are frequent complaints about the inability of offices to share software, so it is doubtful that offices' decisions are strongly linked. Yet, some positive correlation probably occurs because multiple sites perform similar functions and standardize their information processing and training. Hence, vendors may anticipate that success in one location will influence their success elsewhere and bid more aggressively.

investment in system and application software and the less is the flexibility when buying replacements; note that this measure is highly correlated (approx. 0.9) with the total number of mainframes on site, but is only weakly correlated with INVEST, which accounts for a wide array of peripheral equipment. Finally, IBMINC takes on the value one when IBM is the incumbent system vendor at a site. The disadvantages to IBM could stem either from the selective enforcement of procurement rules[12] or from the increased entry of competitors to IBM in the 1970s.

To summarize, the exogenous variables are:

$$\begin{aligned} X_{SUPINC} &= \{\text{INCSYS}\}, \\ X_{SUPNONINC} &= \{\text{COMPSYS}\}, \\ X_{SPECIAL} &= \{\text{DEDAP, SIZE, NETWORK, NONINCUMBENT}\}, \\ X_{INSTALLED} &= \{\text{INVEST, EXPERIENCE, EXPERIENCE2, CAPACITY, IBMINC}\}. \end{aligned}$$

These are substituted in the following equations:

$$f_{NONINC2} = \beta_0 + \beta_{SUPINC} * X_{SUPINC} + \beta_{SUPNONINC} * X_{SUPNONINC} + \beta_{SPECIAL} * X_{SPECIAL} + \beta_{INSTALLED} * X_{INSTALLED}$$

$$f_{NONINC1} = \alpha_0 + [\alpha_{SUPINC} * X_{SUPINC} + \alpha_{SUPNONINC} * X_{SUPNONINC} + \alpha_{SPECIAL} * X_{SPECIAL}] * \delta_1 + \alpha_{INSTALLED} * X_{INSTALLED}$$

$$f_{INC} = \Theta_0 + \Theta_{SUPINC} * X_{SUPINC} + \Theta_{SUPNONINC} * X_{SUPNONINC} + [\Theta_{SPECIAL} * X_{SPECIAL} * \delta_1 + \Theta_{INSTALLED} * X_{INSTALLED}] * \delta_2.$$

Several constraints on the specification help identify the model and impose internal consistency on the results (see Greenstein [1989] for econometric motivation and other specifications). First, an incumbent vendor's supply cannot influence two non-incumbents bidding against each other; that is, $\beta_{SUPINC} = 0$ in $f_{NONINC2}$. Similarly, an incumbent's advantage cannot influence whether a second non-incumbent bids against another non-incumbent, so $\beta_{INSTALLED} = 0$ in $f_{NONINC2}$. Second, the coefficients on factors that influence both the first non-incumbent and the second non-incumbent are constrained to work in the same direction and must have the same proportionate value; i.e., δ_1 must be positive, $\alpha_{SUPNONINC} = \beta_{SUPNONINC}$, and $\alpha_{SUPINC} = \beta_{SUPINC}$. Third, the special characteristics of the requested system are constrained to influence both incumbent and non-incumbent bidding in the same direction and have proportionate values; i.e., $\beta_{SPECIAL} = \alpha_{SPECIAL} = \Theta_{SPECIAL}$, and δ_2

[12] P. R. Werling [1983] argued that oversight especially favored vendors other than IBM and that IBM procurement was more closely monitored, especially in a non-competitive procurement (see pages 177 and 262 and the discussion). Yet, Werling's argument remains largely untested because his quantitative evidence could be interpreted in many ways (Greenstein [1989]).

and δ_1 must be positive. Fourth, the signs on the coefficients for an incumbent's advantages are constrained to be opposite those for a non-incumbent. Moreover, all coefficients measuring an incumbent's advantages have the same proportionate values when measured as disadvantages for a non-incumbent; i.e., δ_2 must be positive, and $\alpha_{INSTALLED} = -\Theta_{INSTALLED}$. Fifth, because it does not affect the coefficient estimates but does aid the estimation of standard errors by freeing up degrees of freedom, α_{SUPINC} and $\Theta_{SUPNONINC}$ are set to zero.[13] Finally, Γ is estimated as a parameter, not as a function of X.[14]

IV. ESTIMATION RESULTS

In the economic model of this study, market conditions influence an agency's anticipation with respect to vendor's bidding behavior and an agency's choice over the use of competitive or sole-sourcing procedures. The results, discussed below, do not reject this econometric specification. Most coefficient estimates are of the right sign, some are statistically significant, and many are economically important. No single economic factor always decides an agency's procedural choice; i.e., some factors are important at some sites but not others. The economic interpretation advanced below contrasts with government publications that do not consider the economic factors influencing an agency's procedural choice (e.g., GAO [1977]).

Table II contains estimates for the log-likelihood function. The coefficient estimates from using uncorrelated errors do not differ much from those using correlated errors, though estimating two additional parameters affects the standard errors. Since the estimates are difficult to interpret, Table III displays simulations using the coefficients. Table III shows the derivatives of the predicted probability of observing competitive bidding with respect to the exogenous variables. Table III also shows changes in the predicted probability of observing competitive bidding that occur in response to changing a continuous variable by one standard deviation. Both simulations set all other continuous variables at their mean value. Table III also gives the changes in probabilities resulting from turning the dummy variables on and off (all simulations are in Greenstein [1989]). The discussion below focuses on Table III.

[13] Log ratio tests for the joint hypotheses $\alpha_{SUPINC} = 0$ and $\Theta_{SUPNONINC} = 0$ could not be rejected at the 10 percent level. Thus, $f_{NONINC1}$ includes only $\alpha_{SUPNONINC}$, and f_{INC} includes only Θ_{SUPINC}; i.e., "rivals" potential supply does not influence one's own bidding.

[14] More elaborate specifications for Γ were estimated, but are not shown for several reasons. Measures of the extent of previous experience with the incumbent are not statistically significant predictors of the probability that an incumbent will win a competitive procurement. The only significant results show that IBM had a slightly lower probability of winning than other firms, that the Air Force stayed with its incumbents more often, and that the Navy switched more often. These specifictions did not change the other coefficient estimates by much, so the predicted probability of sole-sourcing versus competition also did not change. Since the goal of the analysis was to predict choice of procedures rather than the winner of competitive bids (see Greenstein [1993]), it seems best to report the simpler specification.

TABLE II
COEFFICIENT ESTIMATES
(Standard error in parenthesis)

	Uncorrelated Errors	*Correlated Errors*
LOG-LIKELIHOOD	−198.529	−178.421
NUMBER OF OBSERVATIONS	221	221
SOLE-SOURCE, INCUMBENT	26	26
SOLE-SOURCE, NON-INCUMBENT	10	10
COMPETITIVE, INCUMBENT WINS	107	107
COMPETITIVE, NON-INCUMB WINS	52	52
SOLE-SOURCE, NO INCUMBENT	5	5
COMPETITIVE, NO INCUMBENT	21	21
CONSTANT β_0	−0.34	−0.36
	(0.55)	(0.84)
COMPSYS	0.011	0.014
	(0.008)	(0.014)
SIZE	0.078	0.088
	(0.053)	(0.088)
NETWORK	0.033	0.036
	(0.024)	(0.041)
DEDAP	−0.08	−0.06
	(0.097)	(0.14)
CONSTANT α_0	−2.46**	−1.85*
	(0.98)	(1.10)
IBMINC	0.90**	1.01**
	(0.26)	(0.28)
INVEST	−0.11**	−0.08*
	(0.04)	(0.05)
EXPERIENCE	−0.21	−0.32**
	(0.13)	(0.16)
EXPERIENCE2	0.028*	0.045**
	(0.015)	(0.022)
CAPACITY	0.007	0.003
	(0.006)	(0.015)
CONSTANT Θ_0	−2.98**	−3.71
	(3.47)	(2.39)
INCUMBSYS	0.36**	0.29**
	(0.14)	(0.11)
NONINCUMBENT	0.32	0.19
	(0.47)	(0.63)
Γ, PROB OF INCUMB WINNING	0.61**	0.66**
	(0.015)	(0.015)
δ_1	3.91	2.75
	(2.77)	(2.90)
δ_2	1.26**	1.66*
	(0.57)	(1.03)
CORRELATION ε_{INC} and $\varepsilon_{NONINC1}$	—	0.81**
		(0.88)
CORRELATION ε_{INC} and $\varepsilon_{NONINC2}$	—	0.74
		(0.77)

Note: One star means that the t-statistic was greater than 1.64, and two stars means that it was greater than 1.96.

TABLE III
SIMULATED DERIVATIVES AND CHANGES IN PROBABILITIES OF COMPETITIVE BIDDING

When IBM is not incumbent:			*When IBM is an incumbent:*		
	Derivative	*Probability change*		*Derivative*	*Probability change*
COMPSYS	0.0042	0.1099**	COMPSYS	0.0132**	0.0316**
INCSYS	0.0172*	0.0007	INCSYS	0.0006	0.0304**
NETWORK	0.0214*	0.1659**	NETWORK	0.0393**	0.0705**
SIZE	0.0496*	0.1037**	SIZE	0.0910**	0.0495**
INVEST	−0.002*	−0.0991*	INVEST	−0.031**	−0.0194
CAPACITY	0.0001	0.0411	CAPACITY	0.0020**	−0.0004
AVERAGE	−0.0003	0.0357	AVERAGE	−0.0054**	0.0000
DEDAP	—	−0.1029	DEDAP	—	−0.0622
IBMINC	—	0.1415**	IBMINC	—	—

Note: All derivatives are for a site with mean values for all continuous variables. All sites have an incumbent. All acquisitions are not for dedicated applications unless otherwise stated.
One star means that the t-statistic is greater than 1.64 and two stars means that the t-statistic is greater than 1.96. Standard errors are computed by the delta method.
Calculation of changes in probabilities: If V is the continuous exogenous variable, σV is one standard deviation, and $P(V)$ is the endogenous probabilty, then the above were calculated with $[P(V + \sigma V) - P(V)]$. If V is a dummy variable, as with DEDAP or IBMINC, then the above were calculated with $[P(V = 1) - P(V = 0)]$.

The results are consistent with the view that the returns to bidding strongly influence the bidding of potential federal computer vendors and an agency's choice of procurement procedures. The results also echo studies that argue that federal procurement rules increase the fixed costs of bidding (e.g., the Grace Commission [1983]). NETWORK and SIZE are the economically most important exogenous continuous variables; the absolute size of both shifts exceeds those from any other category of variables. A one standard deviation increase in NETWORK increases the probability of observing competitive bidding by 0.07 when IBM was an incumbent and by 0.16 when IBM was not. A one standard deviation increase in SIZE increases the probability of observing competitive bidding by 0.10 when IBM is not an incumbent and by 0.05 when it is. Though DEDAP shifts the probabilities in the predicted direction, other factors often swamp this coefficient.[15]

The results are also consistent with the view that agencies anticipate the potential supply of incumbent and non-incumbent vendors before choosing procurement procedures. This is of interest because theoretical and policy studies of the economic determinants of agencies' procurement decision

[15] Turning DEDAP on or off decreases the probability of IBM's bidding by 0.11, but it decreases a non-IBM incumbent's probability by 0.02. It decreases by 0.06 and 0.10 the probabilities of challengers to IBM and to a non-IBM incumbent, respectively. A one standard deviation in several variables can easily match this magnitude.

underemphasize this factor. Both COMPSYS and INCSYS have the predicted sign, though the statistical significance of each is borderline. Both variables are economically important: for instance, when IBM is not an incumbent, a standard deviation increase in COMPSYS increases by 0.11 the probability of observing competitive bidding, the second largest change in this experiment. A one standard deviation increase in COMPSYS implies approximately 10 more systems in a market segment (or just over two additional firms on average). This is a large effect from a small increase in the number of competitors, particularly in light of the high percentage of procurement that is already competitive.

The installed base of systems does not determine outcomes except where the incumbent vendor is large. The evidence takes two forms: first, when f_{INC} is evaluated at actual data points, in only 54 percent of the cases do the incumbent's advantages add a positive value to the probability of an incumbent's bidding.[16] In most of those cases, the addition is small. Though INVEST is the strongest indicator of an incumbent's advantage, the size of its effect suggests how infrequently the advantages for an incumbent have any economic importance. A one standard deviation increase in INVEST increases by 0.10 the probability of sole-sourcing with the incumbent when IBM is not the incumbent and by 0.02 when IBM is the incumbent. Since this variable averages $1.2 million (in 1967 dollars) with a standard deviation of $2.7 million, its effect is not especially large until it reaches its upper ranges ($25.3 million maximum), when its effect is quite large. But only a few data points are close to these extreme values. Neither EXPERIENCE nor CAPACITY are as important as INVEST.[17]

Second, the estimate of the probability that an incumbent vendor wins a competitive bid is also consistent with the (small) estimates of the effects of installed base. These estimates show that competitive procurement favored incumbents, but did not lockout all non-incumbents. The estimate of $\Gamma = 0.61$ in Table II means that incumbents won 73 percent of the competitive bids in which they participated. In other words, of the 52 cases where a non-incumbent won a competitive procurement, 40 (or 76 percent of the total) represented competition between incumbent and non-incumbent. The other 12 cases were competition between two non-incumbents. Thus, incumbents did bid often (89 percent). The high estimated participation rate of incumbents in this sample (173 of 195 total cases, 147 of 159 competitive cases) and the high winning rate (73 percent) suggests that the expected profitability to incumbents from participating was often positive. Yet, the high participation

[16] This calculation was made by multiplying IBMINC, INVEST, EXPERIENCE, EXPERIENCE2, and CAPACITY by their respective coefficients and summing for each sample observation.

[17] The maximum impact occurs when EXPERIENCE = 3.75, and it is quite small then. The effect of EXPERIENCE reverses in sign for sites where the average age of systems is greater than 7.5. CAPACITY must exceed its range to have a large effect.

rates of non-incumbents (169 of 195) imply that the advantages to incumbency (and disadvantages to non-incumbency) were often not large enough to discourage non-incumbent bidding.

These results also suggest that previous users of IBM tended to obtain systems from market segments where there was more competition than other sectors of the mainframe market. Therefore, IBM users employ competitive procedures more often. When IBM is the incumbent, the probability of competition increases by 0.14, a relative change that few variables match, except at extreme values. This is important because the IBM incumbency dummy is present at 40 percent of the sites.

The results about installed base are of interest for two reasons. First, the previous theoretical emphasis on incumbents' advantages may be overdrawn, at least as far as incumbents' advantages influence procedural choice. Second, the unimportance of an incumbent's advantages contrasts with other analyses of these data (Greenstein [1993b]) that show that factors associated with incumbency (demand for compatibility) do influence an ageny's choice of vendor.

In sum, the above results provide an empirical characterization of the economic determinants of an agency's procedural choice. The competitiveness of procurement differs from case to case, depending on: first, the value of the procurement at the office and related offices and the fixed costs of bidding; second, the potential supply of alternatives in the relevant market segement at the time of the acquisition; and third, to a lesser extent, the buyer's relationship with its incumbent vendor, particularly if that vendor is IBM or if the buyer has made extensive investments with an incumbent.

The main alternative to this economic interpretation is that oversight personnel decided which procurement was competitive and which was not.[18] These alternative views take several different forms, but few go very far. First, strict competitive procedures by the GSA (in its role as the federal government's oversight agency) were widely believed to be more price sensitive than those of an unsupervised agency,[19] which should discourage bidding from incumbent suppliers. Yet, this is not the observed pattern. The opposite occurred:

[18] Oversight could ostensibly produce more competitive procurement (at least on paper) if, as some observers have stated, the satisfaction of procedural requirements for competition became an end in itself, irrespective of the impact on the economic efficiency of the outcome. As the Grace Commission [1983] states: "The Government's (automatic data processing) acquisition process indicates disproportionate concern with 'process accountability'."

[19] GSA procedures were thought to weight less the "soft numbers", such as the expected benefits from future system support, servicing reliability (GAO [1981]), and software-conversion expenses. Until the beginning of the 1980s, GSA evaluation of competitive bids was not systematically accounting for the short-term and long-term costs of converting existing software to incompatible vendors' systems (GAO [1980]). For a summary of this debate and an analysis of related economic issues, see Cabral and Greenstein [1990]. For an in-depth analysis of the way procurement institutions resolve the trade-off between prices and quality, see Greenstein [1993a], or Kelman [1990, chapter 2]..On conversion costs, see Kelman [1990, pp. 103–104], or Greenstein [1991].

incumbents bid on (an estimated) 89 percent of all cases and won most of them.

Second, it is widely believed that the GSA closely scrutinized more valuable procurement. Without further data there is no way to know whether the bidding for valuable contracts would have been competitive in any event or whether GSA encouraged competitive procedures where it would not have occurred. Yet, this view only muddles the interpretation of a single coefficient, SIZE, and no other coefficient.

Third, enforcement of procedural rules may have altered the propensity of agencies to "anticipate" more competition. This is also no problem. It would only affect the estimated constants in the indexes of incumbent and non-incumbent bidding, not the coefficients on the exogenous variables. This does not muddle any coefficient interpretation, nor the study's emphasis on economic factors.

Fourth, Werling [1983] argued that the administration of the Brooks Act slanted GSA's oversight activity against IBM.[20] The above results could be made consistent with Werling's thesis only in a restrictive sense because Greenstein [1993b] shows that an agency's choice of vendor is sensitive to the agency's previous investment with the incumbent. When IBM was involved, GSA's oversight, at most, influenced an agency's procedural choice, but not its vendor choice. Thus, either an agency's procedural choice was a charade and everyone saw through it, or GSA's behavior encouraged acquisitions to be competitive when they would have been anyway. Under either interpretation, economic factors decide outcomes.

V. SUMMARY

This paper attempts to explain the economic determinants of a government agency's choice between competitive procurement procedures and sole-sourcing. It develops a simple empirical model and applies it to the historical computer procurement experiences of US government agencies. The model treats the agency's determination of vendor and of procedure as jointly endogenous. This study shows that the methodology for estimating the economic determinants of discrete outcomes can be usefully extended to bidding data.

In this study several economic factors contribute to an agency's decision

[20] Though Congressman Jack Brooks (D-Texas) retained no formal veto, it was widely believed that he closely monitored the GSA's actions from his position on the House Government Operations Committee (Petrillo [1982]), interfering with a procurement when he pleased (e.g., slowing down approval, holding up funding). Werling states ([1983], p. 262), "Within the (automatic data processing) community it has been common knowledge that the HGOC (House Government Operations Committee) would delay procurement for (automatic data processing equipment) ordered from IBM if at all possible." Also see p. 177 and discussion. Kelman [1990, p. 8] stated that Congressman Brooks was motivated to push for more competition in computer procurement because he feared lack of competition would favor IBM.

concerning an agency's procedure. The extent of potential vendor competition in a market niche, the value of an agency's procurement, and the fixed costs to vendors of bidding are most important, while the advantages attributed to a vendor's being an incumbent are surprisingly weak. Finally, agencies are more likely to engage in competitive procurement if they had experience with IBM's systems.

This paper shows that the same factors that empirically influence an agency's choice of vendor also influence the agency's procedural choice. This suggests that further empirical and theoretical analysis should investigate how an agency's procedural choice influences the optimality of using bidding procedures and the consequences of procurement rule changes. This observation is relevant for empirical, theoretical, and especially policy–motivated analysis.

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