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The Valuation of Complex Derivatives by Major Investment Firms: Empirical Evidence

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ABSTRACT

This article examines the auction of a portfolio of collateralized mortgage obligations (CMOs) to major broker dealers and institutional investors. The unique data set allows us to analyze a number of important empirical questions related to the valuation of CMOs by the bidders and the elasticity of demand for the securities. The results reveal that the valuations differ substantially implying a significant elasticity of demand.

THIS ARTICLE IS DESIGNED to shed light on two related questions. First, it extends the work of Bagwell (1991, 1992), Brown and Ryngaert (1990), and Bradley, Desai, and Kim (1988), among others, on shareholder heterogeneity and the elasticity of the demand for financial assets. To date, the empirical research on investor heterogeneity has focused on common stock. This article supplements previous work by examining an auction of another class of securities, complex collateralized mortgage obligations (CMOs), to major securities dealers and institutional investors.

Second, it provides perspective on fixed income valuation models in the spirit of Cox, Ingersoll, and Ross (1985) and Black, Derman, and Toy (1990). Virtually all of these models, even those that specify relatively complex interest rate processes, assume homogeneous beliefs. This implies that, within the constraints imposed by estimation error, sophisticated investors should place equal values on fixed income securities.

Bagwell observes that investors can be heterogeneous along several dimensions. First, heterogeneity can be induced by tax rules. To the extent that different investors are taxed in different ways, their demand for securities will be affected. Second, transaction costs can cause heterogeneity by driving a wedge between buyers, sellers and owners of a security. Third, investors can differ in their assessments of the value of a security either because they possess different information or because they analyze that information in different ways. Fourth, investors can face different nontradeable risks and, thus, can have different assessments of the value of a security depending on how it interacts with these risks. Finally, it has been suggested by Lee, Shleifer, and Thaler (1991), among others, that investors may differ for idio-

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syncratic or psychological reasons. Because there are numerous potential sources of heterogeneity, when evidence of investor heterogeneity is uncovered, as in Bagwell (1992), it is difficult to infer its source.

In the case of the auction data examined here, the multiple explanations for the heterogeneity problem are largely overcome by the nature of the data. All the bidders are profitable, taxable securities dealers and institutional investors. It is unlikely, therefore, that the tax consequences that result from buying another CMO are likely to be very different across the bidders. Because none of the bidders owns the securities for which they are bidding, transactions costs cannot induce heterogeneity. Differences in inventory holdings across bidders are also unlikely to induce heterogeneity because the value of the auctioned securities is tiny relative to the investment pools of the bidders. Finally, because the bidders are all experienced and sophisticated, it is unlikely that valuations differ for reasons of sentiment. Consequently, significant differences in valuation can be attributed to either asymmetric information or differing valuation methodologies.[1]

The organization of the article is as follows. The data and empirical results are presented in the next section. To anticipate the results, the variance of the bids is huge, much larger than can be explained by estimation error. In light of these results, Section II focuses on possible explanations for the variance of the bids. One obvious candidate is strategic bidding behavior. We show, however, that if bidders bid rationally this cannot be an explanation: under most reasonable conditions, the variance of underlying valuations *exceeds* the variance of the bids. Other explanations for the heterogeneity of the bids including differential taxes, varying inventory positions, and transaction costs are also considered in Section II. The final section discusses the implications of the results in light of the explanations analyzed in Section II.

I. Data and Empirical Results

The data on which this article is based were generated by one of the many legal controversies that arose between brokerage firms and customers regarding losses on CMOs and other derivative securities. In the particular case that gave rise to the current data set, the client company asked that its entire portfolio of CMOs be liquidated with all reasonable speed. A major Wall Street firm was contacted and a procedure for liquidating the securities was negotiated. It was agreed that for a fixed fee the Wall Street firm would conduct an auction to liquidate the securities.

The auction rules were as follows. On day one, the auctioneer would contact a large number of potential bidders and give each of them the terms of the securities that were available for sale including issuer, face amount, maturity,

[1] Asymmetric information, interpreted broadly, subsumes differing valuation methodologies. If two parties have identical information in all respects, presumably they would use the same valuation method. Nonetheless, it is useful to define asymmetric information in a narrower sense to refer to valuation discrepancies that result from using different inputs as distinct from discrepancies that result from using different models.

coupon terms, and repayment conditions. The bidders were then told that if they wanted to bid for any of the securities, their bids must be submitted by 11 a.m. (Eastern Standard Time) on Day two. Only one bid could be placed for any individual security, but each firm could bid on as many securities as it chose. The bids, once received, had to be good until at least 11:20 a.m. Payment terms were to be all cash with a three-day settlement. If the client accepted the highest bid, the securities were wired to the winning bidder on the settlement date. However, the client reserved the right to reject all of the bids and keep the security. After receiving the bids, the client had until 11:15 a.m. to decide whether to accept the highest. In fact, the client selected the highest bid in every case and all the securities were sold by 11:20 a.m. After the auction was over, the client agreed to make the auction information available for research provided that the identity of all parties, including the bidders, was withheld. That data set serves as the basis for this article.

The terms of the securities that were auctioned are presented in Table I. As the table shows, all of the securities are collaterized mortgage obligations issued by either the Federal Home Loan Mortgage Corporation (FHLMC) or the Federal National Mortgage Association (FNMA) and all but two of the issues (Nos. 20 and 22) are inverse floaters. There are 32 different issues with a total face value of $90.6 million. From the standpoint of major dealers and large institutional investors, the securities are "small pieces" because the face values are between $1 million and $13 million.

Despite the fact that the credit risk of the securities is negligible, CMOs are difficult to value because of the interaction between interest rate and prepayment risk. As McConnell and Singh (1994) illustrate, prepayment risk is particularly difficult to assess because prepayments occur for reasons other than minimizing the present value of the borrower's obligation and because the value of many CMO tranches are highly sensitive to prepayments. These complexities make it more likely that potential bidders will disagree about the value of the securities. Nonetheless, it should also be stressed that the bidders had the means to cope with these complexities. Although their identity is confidential, virtually all of the bidders were major securities dealers, well known investment firms, or subsidiaries of well known investment firms that specialized in CMO investments. Given the nature of the bidders, it is reasonable to assume that all of them possessed sophisticated CMO valuation software.

Table I presents the basic terms for each of the 32 issues. Unfortunately, the data given are not sufficiently detailed to estimate the value of the securities. Most importantly, the precise rules for distributing principal repayments are not included. Such detailed information, which is available in the prospectus, is not required for this article because the focus is on bidding behavior of actual investors, not the development of another valuation model by the authors. The purpose of this article is to provide evidence on how actual bidders valued the securities.

The results of the auction are reported in Table II, Panels A and B. Summary statistics related to the auction are presented in Panel A. Twenty-eight firms

Table I

Terms of the 32 CMOs That Were Auctioned

This table gives' the issuer, abbreviated description, CUSIP number, maturity date, quantity, interest rate formula, and any caps, floors, or call features of each of the 32 auctioned CMOs. The issuers are the Federal Home Loan Mortgage Corp. (FHLMC), Federal National Mortgage Assn. (FNMA) and the Federal Home Loan Bank (FHLB).

Lot No.	Issuer	Description as Stated on Cover of Prospectus	Cusip	Maturity Date
1	FHLMC	CMO/series 1225 1225-S-VAR RATE	3129083K0060	03/15/97
2	FHLMC	CMO/series 1227 1227-G-VAR RATE	312909DH4060	05/15/99
3	FHLMC	MTG PARTN CTFS GTD SER 1234 CL 1234-H	312909DT8060	05/15/99
4	FHLMC	CMO/series 1330 1330-I-VAR RATE	312911FH8060	09/15/99
5	FHLMC	MTG PARTN CTFS GTD SER 1421 CL 1421-N	312913PT7060	11/15/22
6	FHLMC	MTG PARTN CTFS GTD SER 1422 CL 1422-SA	312913FU5060	11/15/07
7	FHLMC	SER 1441-SB (inverse floater)	312913TU0060	12/15/97
8	FHLMC	CMO/series 1443-OP-VAR RATE	312913Z33060	12/15/22
9	FHLMC	MTG PARTN CTFS DTD SER 1459 CL 1459-S	312914DX9060	12/15/21
10	FHLMC	CMO/series 1493 S-SEE DESC	312915EP2060	10/15/21
11	FHLMC	MTG PARTN CTFS GTD SER 1516 CL 1516-S	312915D99060	06/15/00
12	FHLMC	MTG PARTN CTFS GTD SER 1537 CL 1537-SA FLTG	312916NN5060	05/15/08
13	FHLMC	MTG PARTN CTFS GTD SER 1541 CL 1541-P	3133TOBY9060	07/15/23
14	FHLMC	MTG PARTN CTFS GTD SER 1543 CL 1543-JB	312916Q28060	07/15/23
15	FHLMC	CMO/series 1543-A MA-VAR RATE	312916R35060	03/15/23
16	FHLMC	CMO/series 1552 LD-VAR RATE	3133TOYW8060	09/15/22
17	FHLMC	MTG PARTN CTFS GTD SER 1566 CL 1566-SB VAR RATE	3133TOJS4060	09/15/00
18	FHLMC	MTG PARTN CTFS GTD SER 1599 1599 CLS	3133T1FW7060	10/15/23
19	FHLMC	MTG PARTN CTFS GTD SER 1608 CL 1608-SC	3133T1X98060	11/15/23
20	FHLMC	CMO/series 1622 E-FIXED RT	3133T1J37060	11/15/23
21	FHLMC	MTG PARTN CTFS GTO SER 1640 CL 1640-SD IO	3133T2ZN3060	12/15/00
22	FHLMC	MTG PARTN CTFS GTD SER 1665 CL 1665-FA FRN	3133T3VU9060	06/15/23
23	FHLMC	MTG PARTN CTFS GTD SER 1743 CL 1743-S	3133T5SX2060	08/15/01
24	FNMA	CMO/series 1992-178 178-SA-VAR-RATE	31358QYS8060	06/25/08
25	FNMA	REMIC pass thru CTF TR 1992-180 CL SG	31358Q5P6060	01/25/22
26	FNMA	CMO/series 1992-200 200-SN-VAR RATE	31358RSK0060	11/25/22
27	FNMA	CMO/series 1992-213 213-S-VAR RATE	31358RL43060	04/25/18
28	FNMA	CMO/series 1992-67 67-S-VAR-RATE	31358MJ88060	05/25/99
29	FNMA	REMIC pass thru CTF TR 93-201 CL SG	31359ESP7060	10/25/23
30	FNMA	REMIC pass thru CTF TR 1993-250 CL SB VAR/RT	31359FWM6060	01/25/17
31	FNMA	CMO/series 1994-39 SA-VAR RATE	31359G2X3060	03/25/24
32	FHLB	CONS BD INT RATE 8.00% TO 10/5/93 & FLTG AFTER	313389FC7060	04/06/98

Table I—*continued*

	TERMS				
Quantity	Rate Formula	Cap	Floor	Period Reset	Callable
1,000,000	22.1% − (2 × 6mo LIBOR)	22.10%	0.00%	Monthly	1% Cleanup call
1,500,000	25% − (2.749 × 1mo LIBOR)	25.01%	0.13%	Monthly	1% Cleanup call
7,533,570	29.88% − (3.415 × 1mo LIBOR)	29.88%	0.00%	Monthly	1% Cleanup call
1,000,000	24.29% − (2.8 × 1 mo LIBOR)	24.92%	0.00%	Monthly	1% Cleanup call
2,000,000	21.7% − (2.33 × D11 COF)	21.70%	0.00%	Monthly	1% Cleanup call
2,000,000	23.4 − (2.6 × 3yr UST)	23.40%	0.00%	Monthly	1% Cleanup call
13,000,000	7.45% − 1mo LIBOR	7.45%	0.00%	Monthly	1% Cleanup call
3,800,000	16.53% − (1.857 × D11 COF)	16.53%	0.00%	Monthly	1% Cleanup call
5,000,000	9.55% − 1mo LIBOR	9.55%	0.00%	Monthly	1% Cleanup call
8,000,000	9.5% − 1mo LIBOR	9.50%	0.00%	Monthly	1% Cleanup call
2,000,000	17.19% − (2.148 × 1mo LIBOR)	17.19%	0.00%	Monthly	1% Cleanup call
1,200,000	16% − (2 × D11 COF)	16.00%	0.00%	Monthly	1% Cleanup call
2,000,000	36.4% − (4.137 × 10yr UST)	33.51%	0.00%	Monthly	1% Cleanup call
1,637,589	52.94% − (4.706 × PRIME)	8.00%	0.00%	Monthly	1% Cleanup call
2,000,000	21% − (2.33 × 1mo LIBOR)	21.00%	0.00%	Monthly	1% Cleanup call
425,000	24.78% − (2.8 × 1mo LIBOR)	24.78%	0.00%	Monthly	1% Cleanup call
875,000	17.27% − (2.333 × 1mo LIBOR)	17.27%	0.00%	Monthly	1% Cleanup call
2,250,000	19.27% − (2.6 × 1mo LIBOR)	19.27%	0.00%	Monthly	1% Cleanup call
1,000,000	21.19 − (2.6 × 1mo LIBOR)	21.19%	0.00%	Monthly	1% Cleanup call
1,000,000	Sequential Payer	0.00%	0.00%	Monthly	1% Cleanup call
10,000,000	7.5% − 1mo LIBOR	7.50%	0.00%	Monthly	1% Cleanup call
1,775,000	10yr UST-50BP	10.00%	0.50%	Monthly	1% Cleanup call
1,000,000	19.2% − (2.4 × 1mo LIBOR)	19.20%	0.00%	Monthly	1% Cleanup call
2,866,667	12.6% − 3mo UST	12.60%	5.00%	Monthly	Non-Callable
3,000,000	12.5% − 3mo UST	12.50%	4.00%	Monthly	Non-Callable
1,000,000	35.57% − (3.72 × 1mo LIBOR)	9.50%	0.00%	Monthly	Non-Callable
5,000,000	9.35% − 1mo LIBOR	9.35%	0.00%	Monthly	Non-Callable
2,250,000	21.72% − (2.3 × 1mo LIBOR)	21.72%	0.00%	Monthly	Non-Callable
2,000,000	24.55% − (4.25 × 1mo LIBOR)	13.00%	0.00%	Monthly	Non-Callable
1,000,000	13.05% − 1mo LIBOR	13.05%	5.00%	Monthly	Non-Callable
1,000,000	10.16% − (0.6 × 1mo LIBOR)	10.16%	5.00%	Monthly	Non-Callable
500,000	14.375% − (2 × 6mo LIBOR)	0.00%	0.00%	Semi-An	Non-Callable

placed at least one bid. As Panel A shows, the average number of bids was approximately nine. Winning bids were divided among twelve different firms with no firm purchasing more than 5 of the 32 issues.

The most striking feature of Panel A is the dispersion of the bids. The average range, defined as the percentage amount by which the high bid exceeds the low bid, is 63 percent! Of course, it is possible that this average is distorted by a few anomalous observations. For example, the data show that the range of bids is larger when the average bid is lower. In particular, several issues have ranges in excess of 100 percent when the minimum bid is less than 2.00 per hundred dollars of face value. On the other hand, the range is zero for one issue because there was only one bid. Excluding both the security for which there was only one bid and the securities for which the minimum bid was 2.00 or less, the average range is still 45 percent. This high average is indicative of the behavior of all the securities. In only three cases, excluding the issue for which there was one bid, is the range less than 20 percent.

There are several other interesting features of the data. If we exclude the issue for which there was only one bid and the issues for which the minimum bid was less than 2.00, the data reveal a relation between the range of bids, average bid, and the maturity date of the issue. For the 7 issues that mature prior to 2000 the average range of bids (average bid) is 24 percent (85.9) while for the 14 issues that mature between 2022 and 2024 the average range of bids is 60 percent (58.7). The relation between bid range and maturity is consistent with the view that bidders use different models or have different beliefs about the interest rate process and/or prepayment function.

To investigate further the surprisingly large dispersion of bids, Panel B of Table II presents all of the individual bids. Panel B demonstrates that the picture conveyed by Panel A is not a result of a few very high and very low bids, nor an artifact of the way the data are summarized. For each security, the bids tend to cover the range between the high and low. There is no tendency for a majority of the bids to clump near a common value with a few extreme bids on either side.

It is also worth noting that the dispersion cannot be attributed to one or two firms always being aggressive bidders and several other firms always low balling. Although some firms, such as numbers 19 and 28, did tend to be more aggressive bidders on average, they were not the highest bidder for many of the securities on which they bid.

II. Possible Explanations for the Results

In this section, we examine several possible explanations for the huge variance in the observed bids for the CMO's documented in Section I. The only explanation found to be consistent with the data is that different dealers have different valuations of these securities due to asymmetric information or differing valuation methodologies.

Table II

Panel A: Bid Summary Statistics

This table gives summary statistics of the results of the auction for each of the 32 CMOs. Information includes abbreviated descriptions, the number of bids, the winning firm, winning bid, minimum bid, average bid, and the bid range.

Lot No.	Description	Number of Bids	Winning Firm	Winning Bid	Minimum Bid	Average Bid	Range (% of Min)
1	CMO/series 1225 1225-S-VAR RATE	16	2	96.13	87.13	93.28	10%
2	CMO/series 1227 1227-G-VAR-RATE	16	19	97.94	80.75	91.54	21%
3	MTG PARTN CTFS GTD SER 1234 CL 1234-H	13	19	99.50	79.50	91.84	25%
4	CMO/series 1330 1330-I-VAR RATE	10	19	96.13	70.00	84.32	37%
5	MTG PARTN CTFS GTD SER 1421 CL 1421-N	7	26	85.13	60.00	74.19	42%
6	MTG PARTN CTFS GTD SER 1422 CL 1422-SA	8	20	81.00	56.00	69.52	45%
7	SER 1441-SB (INVERSE FLOATER)	8	27	2.09	1.06	1.39	97%
8	CMO/series 1443-OP-VAR RATE	12	20	79.00	55.00	69.23	44%
9	MTG PARTN CTFS DTD SER 1459 CL 1459-S	7	19	2.52	0.50	1.61	403%
10	CMO/series 1493 S-SEE DESC	6	9	4.25	2.00	3.27	113%
11	MTG PARTN CTFS GTD SER 1516 CL 1516-S	12	27	86.50	70.00	78.71	24%
12	MTG PARTN CTFS GTD SER 1537 CL 1537-SA FLTG	9	26	68.13	55.13	62.24	24%
13	MTG PARTN CTFS GTD SE 1541 CL 1541-P	7	2	79.00	50.00	68.21	58%
14	MTG PARTN CTFS GTD SER 1543 CL 1543-JB	8	5	60.44	31.00	48.18	95%
15	CMO/series 1543-A-MA-VAR RATE	9	12	73.38	36.50	58.10	101%
16	CMO/series 1552 LD-VAR RATE	9	21	78.00	48.06	64.54	62%
17	MTG PARTN CTFS GTD SER 1566 CL 1566-SB VAR RATE	11	22	78.00	60.00	72.77	30%
18	MTG PARTN CTFS GTD SER 1599 1599 CLS	12	12	47.00	27.75	39.95	69%
19	MTG PARTN CTFS GTD SER 1608 CL 1608-SC	8	21	51.03	26.00	41.45	96%
20	CMO/series 1622 E-FIXED RT	4	20	37.00	32.00	35.14	16%
21	MTG PARTN CTFS GTD SER 1640 CL 1640-SD IO	5	14	2.63	1.50	2.01	75%
22	MTG PARTN CTFS GTD SER 1665 CL 1665-FA FRN	5	19	94.16	90.00	92.73	5%
23	MTG PARTN CTFS GTD SER 1743 CL 1743-S	8	22	85.00	70.00	77.44	21%
24	CMO/series 1992-178 178-SA-VAR RATE	9	12	87.56	68.00	79.95	29%
25	REMIC pass thru CTF TR 1992-180 CL SG	9	27	83.06	65.00	72.71	28%
26	CMO/series 1992-200 200-SN-VAR RATE	8	21	65.00	30.00	49.15	117%
27	CMO/series 1992-213 213-S-VAR RATE	8	28	2.13	0.75	1.51	183%
28	CMO/series 1992-67 67-S-VAR RATE	11	2	96.13	79.50	89.06	21%
29	REMIC pass thru CTF TR 93-201 CL SG	10	28	37.00	20.00	26.73	85%
30	REMIC pass thru CTF TR 1993-250 CL SB VAR/RT	7	2	84.13	65.00	76.87	29%
31	CMO/series 1994-39 SA-VAR RATE	7	27	89.03	72.00	81.48	24%
32	CONS BD INT rate 8.00% TO 10/5/93 & FLTG after	1	28	86.88	86.88	86.88	0%

Table II—*Continued*

Panel B: Bid Data for the Individual Bidders

This table gives the actual bids by each of the 28 bidders for each of the 32 CMOs. Blank spaces mean that the firm did not bid on that particular item.

Lot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	87.13	96.13	93.00			96.00	90.00							
2	87.13	95.13	93.13			97.50	85.00							
3		98.63	98.00								86.47			
4			94.00				70.00							
5		75.13												80.00
6		80.13												
7									1.44					
8		55.00		57.50				78.75			78.13			
9														
10									4.25					
11		78.13		71.00										
12		55.13												
13		79.00							75.50					
14					60.44									
15		65.13										73.38		
16		70.13												
17		76.13				77.00								
18		34.13								37.00		47.00		
19		40.13									40.38			
20														36.00
21														2.63
22				93.81										
23		77.13												
24		83.13										87.56		
25		71.13										80.25		
26				40.50									45.00	42.00
27								1.50					1.38	1.31
28		96.13												84.00
29		21.13					20.00			30.03				23.00
30		84.13												82.00
31		81.13												83.00
32														

A. Strategic Bidding Behavior

One possibility is that the variance of the bids exaggerates the variance of the underlying valuations because of strategic bidding behavior. We examine this possibility by considering the theory of optimal strategies for rational bidders in first-price sealed-bid auctions.

The auction described in the previous section is modeled best as a common value, first-price sealed-bid auction.[2] In particular, we assume that the true

[2] The other polar case is the private value paradigm in which the bidder knows the value of the object to herself, but this value is independent of the value other bidders place on the object.

Table II—*Continued*

15	16	17	18	19	20	21	22	23	24	25	26	27	28
94.84	95.00	91.00		95.66	94.50	90.00			90.00	95.00	95.19	95.06	94.00
94.16	93.25	80.75		97.94	97.50	85.00			86.00	92.00	95.25	92.00	93.00
96.94	93.25	79.50		99.50	88.00	85.00				80.00	97.00	93.59	98.00
		78.50		96.13	87.00	79.00			82.00	90.50	78.00	88.03	
				78.56	60.00	72.00			68.50		85.13		80.00
				68.00	81.00	65.00			56.00	60.00	74.06		72.00
			1.31	1.66		1.06				1.13	1.25	2.09	1.19
				70.13	79.00	60.00		73.53		65.00	68.13	67.56	78.00
			2.50	2.52	1.13	1.75				0.50	0.53		2.38
			2.98	3.75		3.75				2.00			2.88
81.78	82.50	75.25		84.16	80.00	70.00		78.22		81.00		86.50	76.00
				60.25	60.00	65.00		61.16		60.00	68.13	64.50	66.00
				63.00		79.00				50.00		55.00	76.00
				52.00	52.00	45.00		40.00	31.00	45.00			60.00
					60.00	65.40		55.53	36.50	50.00		54.22	62.75
				75.13	51.00	78.00		72.53	56.00	60.00		48.06	70.00
	75.25	73.75			60.00	68.00	78.00		68.00	76.00		77.31	71.00
				45.25	37.00	46.38		33.09	27.75	40.00	44.25	43.06	44.50
					37.00	51.03			26.00	50.00		40.06	47.00
				35.56	37.00					32.00			
			1.67	2.53						1.75			1.50
				94.16	90.00			93.16					92.50
	84.50	71.50		81.38	78.00	70.00	85.00						72.00
				84.25	82.50	70.00		79.34		80.00	84.75		68.00
				74.06	65.75	65.00				70.00	73.16	83.06	72.00
				62.63	30.00	65.00				60.00		48.06	
			2.06	1.53		0.75						1.44	2.13
92.91	95.00	79.50		94.00	88.00	80.00			84.00			96.13	90.00
				33.06	28.00	20.00			20.00			35.06	37.00
				83.72	80.75	65.00			67.50				75.00
				85.34	82.88	72.00			77.00			89.03	
													86.88

value of the security is a random variable, V, which is the same for all bidders but no bidder knows the realization of V. The bidders can obtain information (observe a signal) by doing "research." We assume that each of the n bidders,

Milgrom and Weber (1982) state that the "private value assumption is most nearly satisfied in auctions for nondurable consumer goods. The satisfaction derived from consuming such goods is reasonably regarded as a personal matter, so it is plausible that a bidder may know the value of the good to himself, and may allow that others could value the good differently." The common value paradigm is appropriate in our setting because the item can be sold quickly in a secondary market and, clearly, the value that others place on the item greatly affects the value of the item to any bidder.

denoted by $i = 1, \ldots, n$, observe a signal x_i, which conveys information about V. We assume that the random variables $V, x_i, \ldots, x_n$ are affiliated. Loosely speaking, a vector of random variables are affiliated if some variables having large realizations makes it more likely that the other variables have large realizations.[3] We also assume that the number of bidders, n, is known to all bidders and that all bidders are risk neutral.

We are interested in exploring the relation between observed bids and unobserved valuations (i.e., $E[V|x_i]$) if bidders act rationally. Milgrom and Weber (1982) show that in the environment described above rational bidders do not bid their valuations in a first-price sealed-bid auction for a single, indivisible item.[4] Furthermore, if the auctioned item has a common value to all bidders then the optimal bidding strategy must correct for the fact that winning the item is an informative event. In particular, the winner will be the bidder who has the highest estimate of the item's value, thus, winning conveys bad news to the winner. This is known as the *winner's curse.* Rational bidders reduce their bids to correct for the winner's curse by presuming that they will be the highest bidder. It is not costly to make this presumption if you are not the highest bidder, because losing bidders pay nothing (Milgrom and Weber (1982)).

Computing the exact optimal bidding strategy in our setting would require us to make specific assumptions about the joint distribution of the random variables $(V, \mathrm{x}_{\mathrm{i}}, \ldots, x_n)$. Nonetheless, the key question for interpreting the empirical data is whether the heterogeneity of the observed bids (as measured by the range of bids or the variance of bids) is greater or less than the heterogeneity of the unobserved bidders' estimates of the true value, V.

We do not have a general answer to this question for all possible distributional assumptions. However, an important example is the case where the marginal distribution of $\ln(V)$ is normal with mean μ and variance σ_v^2 and the distribution of $\ln(x_i)$, conditional on V, is normal with mean $\ln(V)$ and variance σ_x^2. If the priors are sufficiently diffuse ($\sigma_v^2 \rightarrow \infty$) the optimal bidding strategy is given by $b_i^*(x) = kE[V|\, x_i = x]$ for some constant $k \leq 1$. Thus, rational bidders will bid some fraction, less than unity, of their valuation. Consequently, in the lognormal case the variance (range) of the bids is always less than the variance (range) of the underlying valuations. It can be shown that for a variety of other reasonable distributions, the variation of valuations is greater than the variation of the bids.[5]

[3] A precise definition can be found in Milgrom and Weber (1982). If random variables are affiliated they are positively correlated but not vice-versa.

[4] In the Dutch auction for share repurchases described by Bagwell (1991) shareholders optimally bid their true valuations. This is true in an environment where multiple units of the same item are being auctioned; prices are nondiscriminatory (i.e., all shareholders receive the same price regardless of their bid); bidders have private, independent values for the item; and bidders are atomistic (i.e., shareholders do not expect to alter the outcome of the repurchase by their behavior). These conditions are not met in our setting.

[5] Wilson (1992) solves for the optimal bidding strategy for various distributional assumptions. As in the example in the text, it is easy to show that the following cases also have the feature that

The data in Panel B of Table II also suggest that the large dispersion of bids is not the result of some bidders who consistently place low bids in the hopes of coming away with a bargain. As noted above, for each security, the bids tend to cover the range between the high and low with few extreme bids on either side. Furthermore, there is no evidence of some bidders always being aggressive bidders and other bidders always bidding low. In light of the foregoing, the observed variation in the bids cannot be explained as an artifact of strategic bidding behavior.

B. A Note on Optimal Auctions

The choice of a first-price auction by the investment bank is also interesting. In a common value setting it is well known that if the bidders' valuations are affiliated then the expected selling price in the English (open cry) auction is at least as large as the expected selling price in the second-price sealed-bid auction which is at least as large as the expected selling price in the first-price sealed-bid auction (Milgrom and Weber (1982) Theorems 11, 15). The intuition for this result is that the open cry auction process generates information about valuations which lessens the effect of the winner's curse and allow bidders to bid more aggressively. In fact, Milgrom and Weber (1982) show that a policy of reporting any information about the item's true value will increase the seller's expected revenue. Consequently, it appears that the seller could have achieved greater revenues by choosing an alternative auction process.

While it may be true that transactions costs preclude the use of an open cry auction, the failure to use a second-price sealed-bid approach is more puzzling. In this regard, the auction used in this case is not unique. The investment bank assured the client that the procedure used to sell his securities was the accepted approach used to liquidate comparable portfolios.

There are several possible explanations for the preference for the first-price sealed-bid auction. First, the client must be made aware that the second-price system is superior. In the case of the client who provided our data, that would have been a time consuming and quite possibly fruitless task. Second, the highest bidder in the auction would have to be reliably informed of the second place bid. Finally, the expected benefits from the second-price auction are not easy to quantify and may not be large. Consequently, individual investment banks have little incentive to bear the costs of changing what has been a common practice. Therefore, the first-price sealed-bid auction may persist for the same type of first mover reasons that sustain the QWERTY keyboard.[6]

the variance of the optimal bids is less than the variance of the underlying valuations: (i) the marginal distribution of V, is normal and the distribution of x_i, conditional on $V = v$, is normal; (ii) the marginal distribution of V is gamma and the distribution of t, conditional on $V = v$, is Weibull where $x_i = -t_i^{-\gamma}$; and (iii) the marginal distribution of V is Pareto and the distribution of x_i, conditional on $V = v$, is uniform.

[6] See David (1985).

C. Inventory Motivations

Another possible explanation for the large variation in the bids is that different bidders hold very different inventories of securities with different risk profiles. Consequently, a bidder's valuation of these securities will depend on the covariance of the nontradeable risk component of the new security with the nontradeable risk of existing inventories.[7] Intuitively, nontradeable risks (i.e., prepayment risk) may not be laid off costlessly while tradeable risks (i.e., interest rate risk) are easily laid off and, thus, should not lead to any differences in valuations across bidders. This suggests that the differences in bids observed in the data above may be driven by the differences in the statistical properties of the inventories held by the bidders.

This condition alone, however, will not produce differences in valuations across bidders because the Modigliani-Miller theorem implies that in the absence of taxes, information asymmetries, and other market imperfections, the value of these securities to all bidders must be the same, regardless of the bidder's existing inventories. Consequently, inventories will lead to heterogeneous valuations among symmetrically informed bidders only to the extent that the auctioned securities interact with existing inventories to alter the firm's future investment opportunities and choices. For example, Froot and Stein (1995) assume that raising new external funds is costly relative to internal funds. Therefore, their analysis implies that the bidders' valuations depend on the extent to which the new securities alter the probability that the bidder will have the internal funds to finance future investments. Alternatively, the new securities may increase the probability of costly bankruptcy if they are positively correlated with existing inventories, thereby inducing heterogeneous valuations among bidders.

The foregoing implies that differences in inventories only have an effect on valuations to the extent that owning the new security affects the future investment decisions of the firm. It is unlikely, however, that these concerns could lead to the large dispersion in bids in our sample because the auctioned items are of almost inconsequential value relative to the investment pools of the bidders. The securities in our sample vary in face value from $1 million to $13 million. The bidders, however, were all major investment banks/dealers with investment pools in the billions of dollars. Consequently, while existing inventories may have a minor impact on the bidders' valuations, the magnitude of the effect is not nearly enough to explain the huge variation in observed bids.

D. Taxes and Transaction Costs

Bagwell (1992) suggests that a possible source of heterogeneity among individual investors is that they may face different tax rates or transactions costs. This is unlikely to explain the dispersion of bids in our sample because (i) in 1995, all the bidders were highly profitable dealers/institutions and,

[7] See Froot and Stein (1995).

presumably, faced the same effective marginal tax rates; (ii) the bidders would have the same basis in the newly purchased securities; and (iii) transaction costs are unlikely to be very different for these major dealers/institutions and are trivial relative to the discrepancies in bids. In addition, it is worth reiterating that the sophistication of the bidders makes it unlikely that the variance of the bids is due to psychological factors such as those proposed by Lee, Shleifer, and Thaler (1991).

In summary, explanations other than asymmetric information and/or differing valuation methodologies are not able to explain the data. Rational bidding theory implies that the variance of the underlying valuations is even greater than the immense variation of the observed bids. Given the nature of the bidders, factors such as taxes and inventory considerations explain at best a fraction of that variance.

III. Implications of the Results

The results reported in this article add further support to the growing body of research that indicates that investors cannot be viewed as homogenous. The dispersion of bids reported in Table II, although not directly comparable to Bagwell's Dutch auction results, conveys the same basic message—different investors place quite different values on the same securities. In addition, these differing valuations cannot be explained as the result of taxes, access to information, or transactions costs. While inventory effects may play some role, they cannot explain valuation ranges on the order of 50 percent. The inescapable conclusion is that major dealers place fundamentally different values on CMOs. Furthermore, our analysis implies that these differences in valuation are due to asymmetric information or differing valuation methodologies.

An immediate implication of the results is that the demand for complex fixed income securities cannot be treated as perfectly elastic. In order to sell increasingly large amounts of CMOs, sellers must attract buyers who place progressively lower values on the securities. More fundamentally, the findings suggest that research on the valuation of fixed income securities should be extended to allow for differing beliefs regarding the underlying interest rate process and prepayment function.

The results also point to the potential value added and profitability of market making. To the extent that there are pronounced differences of opinion among participants in the market, "market knowledge" becomes increasingly important. Traders who have insight regarding which buyers are likely to place high values on a security and which buyers will not value it so highly, can make abnormal profits in the long run, even without independent knowledge of the fundamental value of securities. In the case of the auction that produced the data, the seller was considering selling all of the securities to one firm. The data in Table II demonstrate that no matter which firm was selected, this would have been a poor strategy. By contacting a large sample of potential buyers and conducting an auction, the Wall Street firm clearly increased the net funds received by the client.

Finally, our results suggest that it may be necessary to extend fixed income valuation models to take account of heterogeneous beliefs.[8] The CMO data presented here indicate that sophisticated investors do not agree on some combination of the specification of the model, the underlying interest rate process, or the prepayment function.

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[8] See, for example, Roll (1996).