Walrasian Tâtonnement Auctions on the Tokyo Grain Exchange

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The Tokyo Grain Exchange (TGE)'s *itayose* mechanism provides the opportunity to analyze functioning Walrasian tâtonnement auctions (WTA). In 15,677 auctions conducted over 1997–1998 for corn and redbean futures contracts, price formation is unexpectedly similar to that observed in continuous double auctions. Provisional prices and pledges are informative. In contrast to behavior observed in experiments, few pledges are deceptive, because the traders participate repeatedly and because the auctioneer has flexibility when changing the provisional price and ending the auction. Both the risk of the auction ending and the more equitable dispersion of information increase depth and the speed at which information is embodied in price. (*JEL* D44, D53, G13, G14, Q13)

The Walrasian tâtonnement auction (WTA) dominates economists' theories of how prices form. Even though Walras (1874) developed his ideas from the Paris Bourse [Walker (2001) has refuted that the nineteenth-century Bourse employed auctioneers], such an auction has become a theoretical construct, not believed to describe any currently functioning market. For example, O'Hara (2003, p. 1336) presents the WTA solely as a theoretical foil to actual continuous markets with market makers and informational asymmetries: "The basic Walrasian story abstracts from the actual mechanics of markets. Instead, traders turn in demands to the fictitious auctioneer who aggregates the traders' buy and sell desires."

The Tokyo Grain Exchange (TGE), a futures exchange listing some commodities traded continuously in the pits of the Chicago Board of Trade and the New York Board of Trade, determines prices through *itayose*. This long-standing Japanese mechanism of price formation is a WTA in all but name. The TGE's auctions are conducted by a human

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auctioneer in an hourly cycle, in which a single auction lasts about a minute. These auctions do not punctuate continuous trading but are the sole mechanism for price discovery. The TGE, whose predecessors date to Walras's era, has conducted its auctions electronically since 1988. Electronic transcripts of 15,677 auctions for corn or redbean futures contracts conducted from January 1997 through February 1998 contain each trader's pledges of desired quantities at the provisional prices set by the auctioneer. Encompassing 1,304,322 pledges at 104,293 provisional prices, these transcripts offer the first opportunity to study price formation within a WTA.[1] Put differently, these transcripts offer the opportunity to determine whether the key institutional features of a functioning WTA are those emphasized by theorists.

In the manner of Walker's (1972) characterization of various theoretical versions, a definition of a WTA is needed to draw distinctions with other trading mechanisms. In a WTA, no one, least of all the auctioneer, serves an official market-making function, buying and selling on his own account. The auctioneer calls out (or displays) a provisional price, whereupon traders submit quantity pledges to buy or sell. The auctioneer adjusts the provisional price in the appropriate direction given aggregate excess demand. Some economists [e.g., Cheng and Wellman (1998)] imagine that traders each submit a complete excess-demand schedule, allowing the auctioneer to make further calculations for them, but all an auctioneer needs to commence are pledges from some traders, and those pledges are not necessarily the honest quantities for that provisional price. A WTA is thus distinct from a centralized limit-order book matched periodically by some algorithm, a mechanism Mendelson (1982) has labeled a *clearing house* and Economides and Schwartz (1995) have labeled an *open order book auction*. A WTA is also distinct from storing orders for simultaneous execution, a mechanism studied by Madhavan (1992), because the auction itself takes time during the "groping" (i.e., *tâtonnement*) toward the final price. Nevertheless, a WTA has no rules involving time priority. Traders may revise their pledges with no direct consequences. Even more fundamental is that they do make new pledges. The experimental call auction designed by Schnitzlein (1996) or Theissen (2000), having a single pledge, is distinct from a WTA. In a WTA, only when a provisional price is reached, at which the cumulative pledges clear the market, does the auctioneer transform all outstanding cumulative pledges into trades. Neither the traders nor the auctioneer know beforehand when the auction will end.

Itayose meets this definition of a WTA, while the auctions at many stock exchanges' daily opening do not, however interesting those auctions may be in their own right. As Biais, Hillion and Spatt (1999) have noted

[1] Webb (1991) studied the provisional prices in the TGE soybean market for three months of 1990, but his data did not include each trader's pledge, the sequence of excess-demand, nor the time of the event.

about the modern Paris Bourse, its opening differs from a WTA in three ways. First, supply and demand curves are crossed to find a price implied by those quantities, rather than the reverse. Second, traders know that the preopening period will end at 10:00, regardless. Third, continuous trading follows the opening auction.[2] The deadline effect of the opening and the subsequent continuous trading influence the dynamics of pledges and provisional prices before the opening (Davies, 2003).

Because time passes during a WTA, there are dynamics to price formation. Since the formalization by Samuelson (1941), most theorists have imagined a WTA's dynamics to be a difference equation relating aggregate excess demand as a structural function of the provisional price. That is, traders are imagined to provide the auctioneer with pledges relevant for that provisional price, without themselves ever drawing inferences from the magnitude of the excess demand or without themselves ever anticipating the auctioneer's adjustments. The auctioneer is imagined to contemplate solely the current imbalance, and to adjust the provisional price in proportion to the imbalance. The auctioneer is imagined to iterate the provisional price with a set periodicity, that step size in the limit yielding a differential equation. In this formalization, the dynamics of price formation resemble those of a numerical algorithm. History does not matter.

In continuous auctions, recent history does matter, to market makers who try to learn from the order flow, and to traders who adjust their orders to the prevailing bid and ask. In the process, the responsiveness of price to any prospective order changes. These cumulative changes alter traders' incentive to reveal their private information, which alters, in turn, the rate at which the price embodies information.

Because vector autoregression (VAR) has been used extensively by economists to analyze the dynamics of continuous auctions, as by Hasbrouck (1991) for the New York Stock Exchange, a VAR representation of the TGE auctions allows a comparison of the dynamics of a WTA to those of a continuous auction. To be more specific, a VAR representation of the aggregate of the TGE's traders' cumulative pledges along with the adjustments by the TGE's auctioneer to provisional prices is a major contribution of this article. Should aggregate excess-demand and provisional prices within TGE auctions have a strongly autoregressive structure, Samuelson's formulation would need to be reconsidered. Should the middle of TGE auctions appear indistinguishable from the mid-day of a dealer-dominated continuous market, the supposed differences between the two market-microstructures would be due to the abstractions of theory.

Examining the theoretical WTA, some economists [Otani and Sicilian (1990); Goldberg and Tenario (1997)] have criticized it as encouraging

[2] The Bourse's closing period, between 5:00 and 5:05 P.M., is also not a WTA [Pagano and Schwartz (2003)].

deception by even small traders to under-reveal their desires. Seemingly, this problem has been confirmed in experimental markets [Joyce (1984, 1998); Bronfman et al. (1996)]. Other economists [Medrano and Vives (2001)] have criticized the WTA as allowing large informed traders to deceive others with pledges contrary to their true intentions. The commodities traded on the TGE and the sequencing of TGE auctions provide two natural contrasts in the degree of information dispersion across traders, which should indicate even in aggregate behavior whether deceptive pledging is widespread. To determine which individual traders under-reveal or pursue contrarian strategies is an important use of the transcripts from the TGE, but is beyond the scope of this article. Instead, this article categorizes the many pledges in many TGE auctions, seeking a maximum of the possible extent of deceptive pledging. In any case, this article's results concerning aggregate behavior form the basis of any analysis of the pledging behavior of individual traders. To identify individual traders' pledges as deceptive, periods within auctions when deceptive pledging might be effective would first have to be identified, as through a VAR representation of aggregate behavior. If the dynamics within TGE auctions are similar to those of continuous auctions and if most traders make only a few pledges, which, moreover, seem sensible given the changes to the provisional price, deceptive pledging is unlikely to be widespread. Because deceptive pledging should cause the early provisional prices to have high levels of noise, the informational content of the TGE's provisional prices, measured in the manner of Biais, Hillion, and Spatt (1999), is itself pertinent.

Altogether, the transcripts of TGE auctions allow us to ask: How do traders enter a WTA and how does an auctioneer decide to change the provisional price? How often do traders revise their pledges in ways that could be construed as deceptive? Are provisional prices a noisy signal of the eventual final price or an informative signal, which would imply that traders respond to provisional prices seriously rather than deceptively? How similar are the dynamics within WTAs to those of continuous auctions? For continuous auctions, it has been observed that trades have a persistent impact on prices, an indication that trades convey information. Do pledges, or changes in excess-demand, have a similar persistent impact on provisional prices? Each of these broad questions is answered in sequence in this article's sections, following the next section, which describes in more detail the *itayose* mechanism.

1. Tokyo Grain Exchange Auctions

Itayose can be loosely translated as "session trading" [Ishida (1993)]. In a session, each commodity is auctioned in sequence over its various delivery months, the nearest maturity first. On the TGE, a session takes close to ten minutes per commodity, including about five seconds between auctions.[3] For the period represented by the transcripts, redbean futures contracts of six maturities were sequentially auctioned during six sessions each day and the six corn futures contracts during four sessions each day. Given that trading of a corn futures contract commences one year (about 220 business days) before its expiration, a particular delivery month for corn was auctioned about 880 times. A particular delivery month for redbeans, which commences trading six months before expiration, was auctioned about 720 times, its position in the sessions moving up month by month. No trading of futures contracts occurs except at these sessions.[4]

The prospective direct participants of each TGE auction include an auctioneer situated within the TGE's building, a few individual traders, a small number of trading companies without a brokerage business, and about seventy authorized futures commission merchants (FCMs). An FCM's pledge represents the net among orders placed by its many nonmember customers,[5] orders taken on behalf of the twenty-five or so exchange members who have opted not to rent the dedicated computer terminal, and speculative orders made by the "house trader".[6] At most FCMs, the house trader himself enters the FCM's collective (net) pledge on the remote computer terminal.[7]

Each auction begins when the auctioneer indicates a provisional price, based on the equilibrium price in the previous session and on price movements in intervening auctions for related futures contracts. The pledges in response, identified by FCM or independent trader, are instantly transparent to all participants.[8] The auctioneer adjusts the provisional

3 The commodities are auctioned in a set sequence rather than simultaneously. In 1997, the TGE's four actively traded commodities were, in decreasing volume, corn, soybeans, redbeans, and raw sugar. Currently, two sessions are conducted simultaneously, to accommodate arabica coffee, robusta coffee, non-GMO soybeans, and soymeal.

4 Earlier in the TGE's history, bilateral trades could occur between the multilateral sessions. Currently, designated market makers trade option contracts continuously [Webb et al. (1997)]. By the nature of an organized futures exchange, all trades are as if with the clearinghouse.

5 Customers can and do place limit orders, either during the auctions or as standing orders before. Some customers place market orders before a particular session, while others follow the auctions second by second. Any orders that have accumulated before an auction commences are known only within the relevant FCMs.

6 Following the end of a session, the FCMs report the gross volume represented by their net pledge, distinguishing their house account's transactions from the buys and sells of their customers. The TGE reports total volume by delivery, month, and commodity before the next session, and overnight, reports for each FCM the composition of those trades—new or liquidation of an existing position, customer, or house. House trades represent about 20% of the volume, with considerable variation across FCMs.

7 Even for a brokerage firm with branches throughout Japan, all orders go through one computer terminal, usually located at such an FCM's headquarters. To be clear, what we refer to as "traders" are the direct participants entering pledges at those terminals, not the thousands of indirect participants.

8 Participants can select one of two styles of computer screen displays. One shows all 80 possible participants, in a set location among four columns. The other shows only those so far participating in that auction, in the sequence of the pledges received. In either form, this information can be passed to FCMs' customers.

price by one tick of 10 yen, rather than by his full estimate of the change required to reach equilibrium, although always in the direction of excess demand, which is transparent to traders as well as the auctioneer. The auctioneer and the traders work in real time; the auctioneer, seeing a considerable excess-demand, may not wait for every pledge before adjusting the price, while the traders may enter their pledges anticipating actions by the auctioneer or other traders. Whenever the auctioneer adjusts the provisional price, each cumulative pledge remains valid unless a trader revises it.[9] When revising a cumulative pledge, a trader is not required to "improve" it sensibly (e.g., to reduce a pending buy quantity with an increase in the provisional price). A trader may enter a new pledge even if the auctioneer has not adjusted the provisional price. If at some moment the auctioneer senses the provisional price is the equilibrium, he announces his conjecture by flashing "OK" on the computer terminals. Should any trader's pledge (or a combination of traders' pledges) drive excess-demand to zero while the "OK" is on,[10] the auction ends and pending cumulative pledges become binding trades. If no one takes up this opportunity, the auctioneer adjusts the provisional price while removing the "OK".

Table 1 shows a transcript from a typical TGE auction, one held during the final session on October 1, 1997, for a futures contract specifying delivery of corn at the end of November 1997. The auction's equilibrating price was 16,000 yen, after five intervening provisional prices beginning at 15,950 yen and 10 yen apart. Lasting 40 seconds, the auction comprised 37 pledges by traders and 12 actions by the auctioneer, events shown sequentially in Table 1. Of the 80 authorized traders, 22 participated in this auction and when it ended, 78 November 1997 corn futures contracts traded hands.

Table 1 reveals that TGE auctioneers respond to pledges with a lag, indeed a lag of variable length. For instance, the +27 excess demand that had emerged four seconds into the auction did not prompt the auctioneer to raise the provisional price until 12 seconds later. The series for time between price changes, including the end of the auction, is 16, 5, 6, 5, 5, and 3 seconds. This variable response is at least partially explained by the minimum tick size but likely also explained by the auctioneer's awareness that traders respond to provisional prices with a lag, most likely also a variable lag. When at 15:10:44, the auctioneer proposed 15,960 yen, up one tick from the initial provisional price, the imbalance was +34. At the auctioneer's subsequent upward revisions, the imbalance was +41, +33,

[9] To be clear, what we refer to as a "pledge" is an adjustment to an existing quantity, with the exception of a trader's first entry. That is, a trader with, say, 30 buys pending but wanting 20 buys, enters 10 sells as his next pledge. A trader's cumulative quantity and, if made at the current provisional price, his most recent pledge are visible on the computer screen to all.

[10] One button "take[s] all remaining". Equivalently, a trader can enter a pledge equal to the opposite of the excess demand. By either method, almost always, a single trader ends an auction.

Table 1
Transcript of a TGE auction

Time	Provisional price	OK	FCM	FCM's pledge	FCM's cumulative pledge	Auction imbalance
15:10:28	**15,950**	—				0
15:10:29	15,950	—	YZ	2	2	2
15:10:29	15,950	—	SW	−12	−12	−10
15:10:30	15,950	—	TC	5	5	−5
15:10:31	15,950	—	OM	−1	−1	−8
15:10:31	15,950	—	OC	10	10	−8
15:10:31	15,950	—	TG	−12	−12	−8
15:10:32	15,950	—	MJ	33	33	27
15:10:32	15,950	—	UB	−4	−4	27
15:10:32	15,950	—	CT	6	6	27
15:10:32	15,950	—	OC	−5	5	17
15:10:32	15,950	—	CO	−5	−5	17
15:10:34	15,950	—	OC	5	10	22
15:10:34	15,950	—	YZ	2	4	24
15:10:35	15,950	—	OC	5	15	29
15:10:36	15,950	—	OC	−5	10	24
15:10:37	15,950	—	KN	5	5	39
15:10:37	15,950	—	KY	10	10	39
15:10:37	15,950	—	TB	−5	−5	34
15:10:38	15,950	—	NS	−3	−3	28
15:10:38	15,950	—	YZ	−3	1	28
15:10:39	15,950	—	AC	10	10	38
15:10:40	15,950	—	DO	−5	−5	33
15:10:41	15,950	**OK**				33
15:10:43	15,950	OK	OM	1	0	34
15:10:44	**15,960**	—				34
15:10:45	15,960	—	OC	5	15	39
15:10:45	15,960	—	YG	2	2	41
15:10:47	15,960	**OK**				41
15:10:49	**15,970**	—				41
15:10:52	15,970	—	IG	2	2	43
15:10:52	15,970	—	MU	−5	−5	33
15:10:52	15,970	—	TB	−5	−10	33
15:10:52	15,970	**OK**				33
15:10:55	**15,980**	—				33
15:10:57	15,980	—	KN	5	10	38
15:10:58	15,980	**OK**				38
15:11:00	**15,990**	—				38
15:11:02	15,990	—	TB	−1	−11	37
15:11:03	15,990	**OK**				36
15:11:03	15,990	OK	NS	−1	−4	36
15:11:05	**16,000**	—				36
15:11:06	16,000	—	ST	−1	−1	28
15:11:06	16,000	—	YZ	−7	−6	28
15:11:07	16,000	—	YT	−3	−3	25
15:11:08	16,000	—	CO	−2	−7	23
15:11:08	16,000	**OK**				23
15:11:08	16,000	OK	OT	−3	−3	20
15:11:08	16,000	OK	OC	−20	−5	0

This auction was conducted during the final session on October 1, 1997 for the first-position November 1997 corn futures contract. The equilibrium price was 16,000 yen per tonne. At that price, the final volume (buys or sells) was seventy-eight lots of 100 tonnes. Twenty-two FCMs participated: thirteen selling at the final price, eight buying, and one dropping out. The auctioneer's actions are in bold.

+38, and +36, which are not the monotonic decreases that should have happened were pledges responses solely to the current provisional price.

Organized by seconds rather than by events in the auction, Table 2 shows a transcript of a TGE auction held on the same date and session for sixth-position corn, September 1998. The auctioneer's initial provisional price of 15,480 yen, up 40 yen from the session two hours before, was the equilibrating price. Although this sixth-position auction was more active than the first-position auction shown in Table 1, involving 150 pledges

Table 2
Second-by-second course of a TGE auction

Time	Provisional price	OK	FCMs pledging that second	Sell pledges	Buy pledges	Auction imbalance
15:15:24	**15,480**	—	—	—	—	0
15:15:25	15,480	—	1	3	0	−3
15:15:26	15,480	—	4	7	43	33
15:15:27	15,480	—	3	10	8	31
15:15:28	15,480	—	6	92	32	−29
15:15:29	15,480	—	5	9	151	113
15:15:30	15,480	—	3	0	120	233
15:15:31	15,480	—	8	27	33	239
15:15:32	15,480	—	5	2	55	292
15:15:33	15,480	—	4	2	21	312
15:15:34	15,480	—	7	91	106	327
15:15:35	15,480	—	7	37	81	371
15:15:36	15,480	—	6	25	110	456
15:15:37	15,480	—	3	13	19	462
15:15:38	15,480	—	3	49	19	432
15:15:39	15,480	—	2	24	10	418
15:15:40	15,480	—	4	25	15	408
15:15:43	15,480	—	2	5	5	408
15:15:44	15,480	—	5	19	4	393
15:15:45	15,480	—	5	62	4	335
15:15:46	15,480	—	3	12	5	328
15:15:47	15,480	—	7	19	19	328
15:15:48	15,480	—	5	38	1	291
15:15:49	15,480	—	2	0	60	351
15:15:50	15,480	—	5	71	30	310
15:15:51	15,480	—	6	46	29	293
15:15:52	15,480	—	4	4	16	305
15:15:53	15,480	—	3	14	2	293
15:15:54	15,480	—	3	6	0	287
15:15:55	15,480	—	3	5	6	288
15:15:56	15,480	—	1	3	0	285
15:15:57	15,480	**OK**	4	56	2	231
15:15:58	15,480	OK	1	4	0	227
15:15:59	15,480	OK	7	52	7	182
15:16:00	15,480	OK	2	32	0	150
15:16:01	15,480	OK	2	20	4	134
15:16:02	15,480	OK	5	30	52	156
15:16:03	15,480	OK	2	1	30	185
15:16:04	15,480	OK	1	5	0	180
15:16:05	15,480	OK	2	180	0	0

Conducted during the final session on October 1, 1997, this auction was for the September 1998 corn contract, the sixth position. Over the 41 seconds, there were 150 pledges made by 52 FCMs, two of whom dropped out before the auction ended with 643 lots of 100 tonnes exchanged. The equilibrium price of 15,480 yen per tonne, up 40 yen from the previous session, was the only price proposed by the auctioneer, whose actions are in bold.

by 52 traders, it lasted but one second longer. At every second in the auction at least one trader made a pledge. During many seconds, five or more traders entered a pledge (a pace too fast for observers to distinguish events). The peak imbalance of +462 occurred 13 seconds into the auction. Over the next 28 seconds, pledges to sell 782 lots were made, but so were a further 320 buy pledges. Over the last eight seconds, while the auctioneer indicated "OK", pledges to buy continued amid the predominance of sell pledges.

The OK sign is an essential feature of *itayose*. As when changing the provisional price, the auctioneer uses his judgment about indicating "OK".[11] In the auction represented by Table 1, the auctioneer first displayed "OK" at 15:10:41, despite the +33 excess demand (and the subsequent need to raise the price five ticks). In the auction represented by Table 2, the auctioneer displayed "OK" when the imbalance was +231, a large fraction of either the peak imbalance or the ultimate volume of 643 lots. In effect, the OK sign is an observable signal of the auctioneer's uncertainty about a futures contract's value. It is simultaneously a proxy of the risk to traders of an auction ending.

The means reported in Table 3 for auctions held from January 1997 through February 1998 confirm the interactions among traders' presence, price changes, and the OK sign. During these 6073 corn auctions, TGE auctioneers signaled "OK" 25,814 times among the 45,339 provisional prices they proposed; during 9604 redbean auctions, they signaled "OK" 47,126 times among 58,954 provisional prices.[12] TGE auctioneers use the OK sign more aggressively the lower the average volume, more aggressively in the sense that more time elapses after the first "OK" and that the provisional price must often be changed nonetheless. Even for sixth-position corn, the most actively traded futures contract on the TGE, on average 29.77% of price changes are made after the first "OK", not to mention that 9.32% of traders pledge for the first time.

Even though each TGE auction is distinct, TGE auctions fall into patterns. FCMs' customers participate over many months or years, the house traders enter pledges auction after auction, and the TGE staff conducting the auctions is permanent. Over January 1997 through February 1998, the level and spreads within both corn and redbean futures prices remained fairly stable, at least by the standard of futures markets. Such consistency suggests TGE auctions across those 14 months can be

[11] The auctioneer cannot indicate "OK" if the excess demand is extreme—outside ±300 lots for corn, outside ±100 lots for redbeans—but he would be unlikely to do so. In part, the auctioneer uses the OK sign to ignore excess demands of zero reached inadvertently early in an auction.

[12] The electronic transcripts for 55 auctions over these 14 months had become corrupted, while another 249 auctions at the time experienced a computer delay or an obvious error, such as a huge pledge of 5000 lots reversed not long thereafter. Rather than attempt reconstructions, we excluded these auctions. A further 862 auctions hit the day's price-move limit, and so ended in a lottery, itself an interesting feature of the TGE.

Table 3
Summary statistics across session and position

Means for corn auctions

	Session						Position (2 months apart)					
Variables	9:00 A.M.	10:00 A.M.	11:00 A.M.	1:00 P.M.	2:00 P.M.	3:00 P.M.	1st	2nd	3rd	4th	5th	6th
Price changes	8.24	—	6.82	7.65	—	6.87	12.45	8.57	6.00	5.57	5.65	5.89
Percentage of price changes after "OK"	47.04	—	45.00	55.61	—	47.75	71.49	59.75	53.45	43.39	33.19	29.77
Seconds elapsed	97.76	—	86.83	75.28	—	84.07	97.02	84.78	77.00	78.31	85.23	94.50
Percentage of seconds after first "OK"	49.40	—	47.69	54.71	—	49.84	69.10	59.58	53.40	45.08	37.96	35.74
No. of traders	38.75	—	39.19	35.96	—	38.78	22.29	28.55	35.92	42.02	48.20	53.36
Percentage of traders after first "OK"	22.69	—	18.82	28.00	—	20.63	42.46	31.01	22.59	16.86	11.42	9.32
No. of contracts in a pledge	12.49	—	12.95	12.79	—	13.46	7.76	9.38	11.16	14.32	17.32	17.96
Final within-auction volume	368.71	—	358.86	309.34	—	371.91	87.27	143.36	239.34	371.79	567.88	729.81
Number of auctions	1577	—	1555	1484	—	1457	1052	1021	1004	1012	1002	982

Table 3
(Continued)

Means for redbean auctions

	Session						Position (One month apart)					
Variables	9:00 A.M.	10:00 A.M.	11:00 A.M.	1:00 P.M.	2:00 P.M.	3:00 P.M.	1st	2nd	3rd	4th	5th	6th
Price changes	7.39	5.77	5.29	6.37	5.22	5.90	6.45	6.54	5.90	5.57	5.71	5.78
Percentage of price changes after "OK"	60.31	59.34	56.96	64.57	57.81	59.07	64.23	67.78	65.68	60.71	51.62	47.49
Seconds elapsed	81.19	67.28	67.38	60.42	65.96	69.58	60.06	64.65	66.61	69.36	72.42	79.75
Percentage of seconds after first "OK"	59.18	59.79	58.31	62.43	58.99	59.58	67.35	66.50	63.26	58.99	52.20	49.42
No. of traders	25.63	21.39	21.19	21.56	20.18	22.16	9.84	14.70	19.20	24.18	29.71	35.29
Percentage of traders after first "OK"	27.72	33.98	31.02	36.94	31.75	32.29	43.02	41.23	36.22	30.65	23.84	18.20
No. of contracts in a pledge	6.84	6.48	6.67	6.71	6.70	7.34	3.88	5.17	6.17	7.54	8.87	9.13
Final within-auction volume	136.13	96.54	97.52	98.89	91.97	120.27	23.29	41.98	68.02	109.80	171.53	232.81
Number of auctions	1659	1650	1630	1577	1571	1517	1634	1609	1605	1603	1597	1556

The table reports the means calculated for each session and position of 6073 corn and 9604 redbean futures contract auctions held from January 1997 through February 1998. Some other auctions were excluded because the provisional price hit the price-move limit before the equilibrium could be reached (576 corn and 286 redbean auctions), because some obvious error by a participant delayed the auction (187 and 62, respectively), or because the transcripts for the auctions are incomplete (27 and 28, respectively). The row titled *Price changes* reports the average number of times the auctioneer adjusted the provisional price during an auction and *percentage of price changes after "OK"* is the percentage of price changes occurring after the auctioneer first indicated "OK". *Seconds elapsed* refers to the number of seconds it took for an auction to reach equilibrium. *No. of traders* are those directly participating in a particular auction. *Final within-auction volume* is the cumulative pledges for futures contracts either bought or sold, apart from the sizable quantity matched within FCMs.

aggregated, as in Table 3.[13] The means reported in Table 3 suggest that auctions are much the same regardless of time of day.[14] The one clear substantive difference among auctions for each commodity is by the position of the futures contract.[15] In the analysis that follows, we aggregate auctions during the 14 months except by position.

2. Temporal Patterns of Price Changes and Pledges

But for the exceptions caused by price-move limits, TGE auctions reach an equilibrium price. From this fact it follows that there exists, among the repeated auctions for a commodity and position, some systematic relationship between the time series for excess demand and the time series for the changes in the provisional price. The question is whether these related time series behave as expected, whether predicted from theory or from impressions of related mechanisms of price formation.

Contrary to prevailing theories, a TGE auctioneer does not change the provisional price as the metronome of a difference equation. The time between adjustments not only varies but varies systematically with variables the auctioneer can observe at the moment he changes the provisional price. According to the regression coefficients in Table 4, the auctioneer, having just begun an auction, waits extra time—between 12 and 21 seconds depending on the commodity and position.[16] He waits three or four seconds more than otherwise if the excess demand directs him to return to a provisional price that he has already tried, just as he waits longer if he has concluded that the OK sign is appropriate. He waits longer if he sees more traders than usual participating at that point in the auction, holding constant the excess demand, just as he speeds up adjustment of the provisional price if the excess demand is substantial.[17]

[13] In a few auctions, the provisional price oscillated 2, 3, or even 4 times between two prices one tick apart, most likely because of limit orders. We compressed these auctions (114 for corn and 331 for redbeans) to the moment of the first repeat of what became the final price.

[14] The principal exception is the auction for first-position corn at the first session. This auction averages many more price changes, to reflect the movement overnight in Tokyo on the CBOT.

[15] To provide statistical backing to these statements: In a regression explaining the number of traders participating in an auction with session in the day, position of futures contract, quarter in the year, prevailing spreads (e.g., backwardation), and recent price variability, the principal explanatory variables relate to position. Recent price variability does matter slightly, which may reflect the dominance of speculators rather than hedgers on the TGE. The R^2 in this regression is 0.66 for corn and 0.62 for redbeans.

[16] The "first" variable, representing whether the price change was an auction's first, alone provides an R^2 of between 0.27 and 0.37. By implication, as a group, the other explanatory variables in Table 4 are statistically significant.

[17] On purely econometric grounds, the regression specification in Table 4 can be questioned. The number of traders who have so far participated in an auction, not to mention the excess demand itself, depends on the auctioneer's past and present actions; the auctioneer himself considers the timing of changes in the provisional price when he puts on the OK sign. All properly are endogenous variables. Even so, the fact that the timing of the auctioneer's price adjustments should be included in a larger system only reinforces the conclusion that WTAs' dynamics are not a single and simple difference equation.

Table 4
Regression estimates of number of seconds between changes in provisional price

	Position of corn futures contract					
	1st	2nd	3rd	4th	5th	6th
First	12.703	14.852	18.404	19.406	20.492	20.856
	(97.71)	(85.28)	(75.98)	(74.35)	(66.88)	(62.35)
Tried previously	3.105	3.274	3.476	2.672	2.079	2.199
	(26.99)	(20.22)	(14.84)	(10.79)	(6.98)	(7.20)
"OK" on	3.331	4.132	4.982	6.344	8.513	9.723
	(35.85)	(30.27)	(23.12)	(29.18)	(32.22)	(33.51)
No. of traders	0.134	0.186	0.302	0.335	0.390	0.445
	(28.89)	(25.19)	(28.70)	(29.40)	(29.40)	(29.05)
Absolute value of excess demand/100	−0.328	−0.292	−0.458	−0.348	−0.366	−0.360
	(12.74)	(8.30)	(8.10)	(8.58)	(10.58)	(12.25)
Constant	1.831	0.398	−3.764	−5.832	−8.658	−11.904
	(14.27)	(1.74)	(9.02)	(12.35)	(14.41)	(15.13)
No. of adjustments to provisional price	12,089	7765	5102	4690	4723	4897
R^2	0.58	0.60	0.63	0.66	0.65	0.62
Standard deviation of residual (seconds)	3.65	4.58	5.88	6.15	7.12	7.65

	Position of redbean futures contract					
	1st	2nd	3rd	4th	5th	6th
First	11.538	11.995	14.191	15.510	15.949	17.023
	(95.14)	(97.37)	(96.86)	(90.33)	(86.44)	(83.17)
Tried previously	3.872	4.043	4.313	4.006	4.042	3.252
	(30.13)	(33.32)	(29.80)	(24.49)	(22.38)	(16.29)
"OK" on	−0.333	1.788	3.028	4.034	5.363	7.402
	(0.85)	(7.59)	(13.05)	(18.76)	(31.10)	(41.27)
No. of traders	0.200	0.197	0.183	0.220	0.222	0.285
	(26.70)	(26.19)	(23.75)	(26.87)	(27.51)	(31.58)
Absolute value of excess demand/100	−3.266	−2.086	−1.066	−0.976	−0.424	−0.352
	(15.07)	(15.24)	(8.29)	(9.60)	(7.63)	(8.31)
Constant	5.983	3.730	2.345	1.043	−0.309	−3.168
	(14.40)	(13.41)	(8.03)	(3.56)	(1.15)	(9.69)
No. of adjustments to provisional price	9098	9167	8016	7572	7844	7653
R^2	0.53	0.58	0.59	0.59	0.59	0.60
Standard deviation of residual (seconds)	3.93	3.98	4.65	5.34	5.75	6.36

This table reports results from estimating over observations from all auctions with at least one price change

$$Seconds_i = \alpha + \beta_1 First_i + \beta_2 Tried_i + \beta_3 OK_i + \beta_4 Traders_i + \beta_5 AvgExD_i + \varepsilon_i$$

where $Seconds_i$ is the number of seconds the i-th provisional price was proposed in a particular auction, $First_i$ is a dummy variable indicating if $i = 1$, $Tried_i$ is a dummy indicating if the excess demand implies an adjustment to a provisional price that has been tried previously, OK_i is a dummy variable indicating if the "OK" sign was posted while the i-th provisional price was proposed, $Traders_i$ and $AvgExD_i$ are, respectively, the number of participating traders to that point in the auction and the average absolute value of excess demand existing while the i-th provisional price was operative. Absolute values of t-statistics are in parentheses.

The timing of changes in the provisional price is under the direct control of a TGE auctioneer, whereas the time series for excess demand results from the distinct actions of the many traders, not to mention the FCMs' many customers. According to Figure 1 panel A, traders in the aggregate enter an auction gradually. For instance, within sixth-position auctions for corn or redbeans lasting between 60 and 120 seconds (for the great majority of such auctions), only half of the ultimate participants have entered their first pledge by the 10th second. A relevant fraction of traders make their first pledge between 20 and 30 seconds into an auction, by which time the auctioneer has usually changed the provisional price at least once.[18] According to Figure 1 panel B, which plots the average rate at which traders make pledges, traders tend to pledge actively during the early stages of an auction but their rate of pledging drops rapidly and stabilizes soon after the start of an auction. Nevertheless, according to panel C the average size of a pledge is the same at any moment in an auction, with the exception of the first seconds of corn auctions, when some minor FCMs place their single small pledge. None of these temporal patterns in pledging accord with the theories inaugurated by Samuelson (1941).

The temporal patterns of pledge size and entry rates at the TGE are also opposite those observed at other groping-style mechanisms. For instance, Biais, Hillion, and Spatt (1999) have observed that at the Paris Bourse, order placement spikes at the very end of the preopening. Camerer (1998) has found that during pari-mutuel horse betting, where bets can be revised and canceled at any point before the start of a race, both the rate at which bets are placed and the average size of a bet rise sharply towards the end. In both these mechanisms, participants know *ex ante* how long the groping lasts and there are no incentives to encourage participants to place orders early. Evidently, the uncertainty about when a TGE auction will end induces traders to participate early, even if not immediately.

The generally declining pattern of traders' pledging activity through an auction does accord with Vives's (1995) model of a tâtonnement auction comprising risk-averse, competitive "informed" traders, liquidity traders, and risk-neutral competitive market-makers, who he also interprets as an auctioneer. Vives's intuition is that as an auction proceeds and the provisional price moves closer to equilibrium, the incentive for informed-competitive traders to pledge aggressively decreases, while the pledging behavior of liquidity traders is unaffected. Vives's model does not constrain the hypothetical auction to end at a set time.

[18] In the relatively short auction in Table 2, at 41 seconds too short to be included in Figure 1, 10 of the 52 participants had not entered by the 20th second, and 5 of those 10 waited until the OK sign was on beginning with second 32.

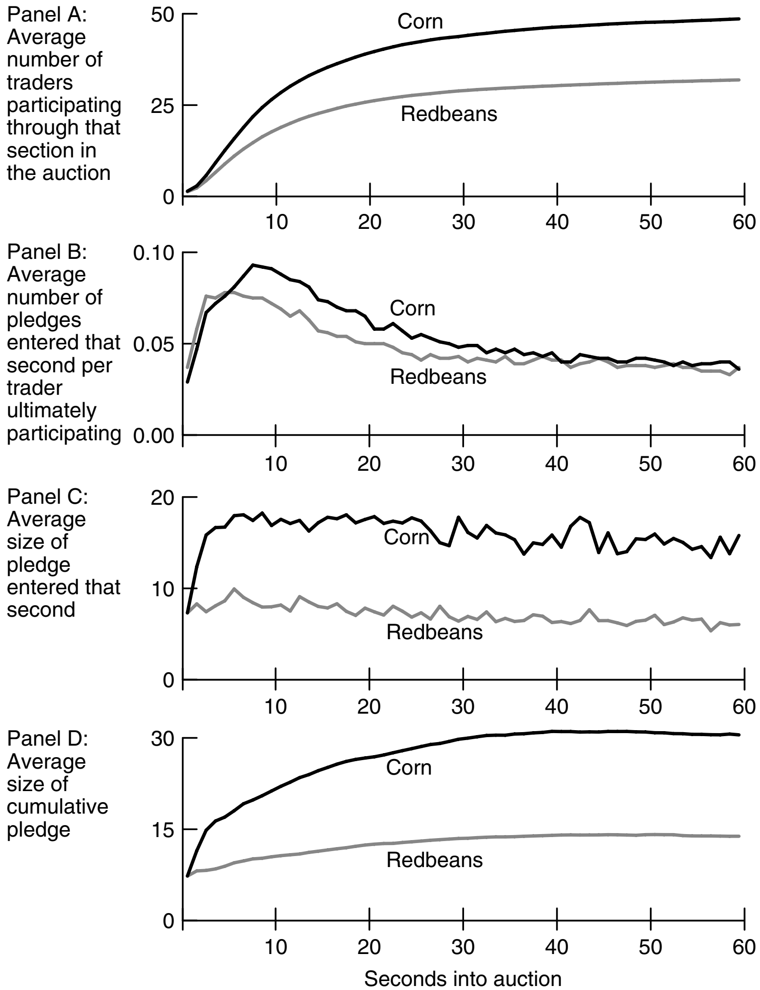

Figure 1
Traders' pledging behavior as a function of time elapsed. The averages are over sixth-position auctions lasting between 60 and 120 seconds, 518 auctions for corn and 776 for redbeans.

The pattern of pledges in Figure 1 panel B does not, however, accord with the U-shaped pattern predicted by Medrano and Vives (2001), who focus on a large player with private information. Their intuition is that when the risk of an auction ending is low, a large strategic insider would attempt to keep the provisional price away from the value of the asset by pledging aggressively and contrary to her private information. Her pledging activity would then subside, until the prospect of equilibrium is very high, at which time she would pledge aggressively and in accord with her private information. Such behavior should be seen in an increase at the right of panel B.

From the perspective of deceptive pledging, most interesting is the average size of the cumulative pledge as an auction progresses. The average cumulative pledge in Figure 1 panel D does increase with time, more so for corn than for redbeans, a pattern consistent with strategic under-revelation. But the average cumulative pledge stabilizes by second 30, earlier than when these sixth-position auctions almost always end. Although the increasing size of the average cumulative pledge may result from traders fragmenting their pledges to reduce their effect on price, more likely it results from the habits of particular FCMs, often those handling smaller volumes, to enter auctions early, or from similar habits among customers within each active FCM. Those habits of timing may involve strategic calculations, but calculations at another level removed from the specific interaction in any one auction between excess demand and changes in the provisional price. Whatever the reason, panel D indicates that pledges are autoregressive early in auctions.

3. Prevalence of Deceptive Pledging

Deceptive pledging, whether by small traders perceiving an incentive to under-reveal or by a large insider misleading others, necessarily involves pledges that are not serious and that must later be revised. Examples of seemingly deceptive pledges can be found in TGE auctions. In the auction in Table 1, trader KN pledged to buy 5 at the initial provisional price; 20 seconds and two upticks later, KN pledged a further +5, a pledge irrational on its face, because a willingness to buy should be lower at a higher price, but a pledge that could result from a strategy of under-revelation. Similarly, trader OC might seem to have succeeded in a contrarian strategy, having ended the auction by switching his cumulative pledge from +15 to −5 with a "take-all-remaining" pledge of −20.

The prevalence of deceptive pledging cannot be deduced by a simple count of contrarian or increased cumulative pledges, however, because some of those revisions may have been in response to the auctioneer's changes to the provisional price. Trader OC's switch from a buy to a sell could have been a straightforward response to the higher provisional price. For that matter, traders NS, CO, or TB, whose increased offers to sell with the higher provisional price seem rational on the face, might have been under-revealing their full willingness to sell at the initial provisional price.

Given the ambiguity about traders' motives in the context of changes in the provisional price, the detection of deceptive pledging inevitably involves a probabilistic interpretation. If deceptive pledges were common, a large proportion of modifications of cumulative pledges would not be rationalized by corresponding changes in the provisional price. In particular, the percentage of contrarian pledges would seem out of proportion to other revisions, especially among initially large pledges. Strategic under-revelation would be manifest in asymmetric increases in quantities. Because deceptive behavior would presumably be most effective during those auctions less likely to be active, the proportion of seemingly irrational pledges would be higher in first-position than for sixth-position auctions and higher for redbeans than for corn.

Whether seemingly deceptive pledges are disproportionate can be determined from Tables 5 and 6. In Tables 5 and 6, for first-position and sixth-position auctions for corn and for redbeans, every pledge by every trader is categorized. The categorization by row concerns whether the pledge was the trader's only one during the auction or part of a sequence, and if part of a sequence, whether it accorded with the changes in the provisional price. The categorization by column concerns whether the pledge results in a cumulative sell, buy, or cancellation, should sellers and buyers pursue different strategies. As it happens, the columns for sells and buys are little different in their composition by row, which contradicts the behavior in experiments reported by Joyce (1984). Overall, Tables 5 and 6 provide evidence that deceptive pledges are not prevalent.

A single pledge, especially one made at the initial provisional price, is unlikely to be anything but serious. Such single pledges are common within TGE auctions. In the auction in Table 1, of the 22 participants, 15 made a single pledge, 9 of those at the initial price. In the auction in Table 2, 22 of the 52 made a single pledge. Over all auctions, the percentage of single pledges at the initial provisional price out of all pledges, namely, row A in Tables 5 and 6, is as high as 18.96%, for first-position redbeans, which are the auctions in Tables 5 and 6 with the lowest intrinsic volume. Most, if not all, of pledges in row B, those made after the initial provisional price but rational given the change, are likely to be serious, which implies another 9.03% of all pledges for first-position redbeans. Out of all first pledges, the percentage, not modified (namely, rows A through C as a percentage of rows A through F), ranges from a low of 28.12% for sixth-position corn to 58.13% for first-position redbeans.[19] A single pledge made after an adverse change in the provisional price, namely row C, could be deceptive under-revelation—although it is not obvious why a strategy of delay would dominate a strategy of delay and splitting the true pledge—but it cannot be part of a contrarian strategy.

Modifications are the most likely indication that the original pledges were not serious. The most common subsequent pledges, however, are those in the category of sensible given the change in the provisional price, namely, row J in Tables 5 and 6. Relatively few subsequent pledges

[19] Biais, Hillion, and Spatt report a similar percentage for single pledges entered during the preopening period at the Paris Bourse.

Table 5
Styles of pledging during corn auctions

Characteristics of pledge	First-position auctions				Sixth-position auctions			
	Seller	Buyer	Cancel	Total	Seller	Buyer	Cancel	Total
A. Only pledge, at initial provisional price	5.41	5.49	0.00	10.90	2.29	2.44	0.00	4.74
B. Only pledge, entered after initial price, and rational	3.15	2.99	0.00	6.14	0.65	0.62	0.00	1.26
C. Only pledge, entered after initial price, and irrational	1.46	1.72	0.00	3.19	0.30	0.33	0.00	0.63
D. First pledge of a sequence, at initial price	6.68	6.45	0.00	13.13	7.04	7.51	0.00	14.56
E. First pledge of a sequence, after initial price, and rational	2.29	2.01	0.00	4.29	0.76	0.59	0.00	1.36
F. First pledge of a sequence, after initial price, and irrational	2.40	2.13	0.00	4.53	0.45	0.50	0.00	0.95
G. Subsequent pledge, at same price, and larger	4.21	3.96	0.00	8.17	11.88	11.22	0.00	23.10
H. Subsequent pledge, at same price, and smaller	2.47	2.30	1.63	6.40	7.72	7.71	1.65	17.08
I. Subsequent pledge, at same price, and contrary	0.75	0.87	0.00	1.61	2.49	2.34	0.00	4.83
J. Subsequent pledge, at a later price, rational, and not contrary	10.28	9.50	6.49	26.27	8.69	8.30	1.70	18.68
K. Subsequent pledge, at a later price, rational, and contrary	1.51	1.41	0.00	2.92	1.11	1.12	0.00	2.23
L. Subsequent pledge, at a later price, irrational, and larger	4.04	4.27	0.00	8.30	3.20	2.98	0.00	6.19
M. Subsequent pledge, at a later price, irrational, and smaller	1.20	1.11	0.95	3.27	1.48	1.56	0.47	3.52
N. Subsequent pledge, at a later price, irrational, and contrary	0.42	0.46	0.00	0.88	0.46	0.43	0.00	0.89
Total	46.26	44.66	9.08	100.00	48.52	47.66	3.82	100.00

Every pledge is placed into fourteen rows, depending on its relationship to that trader's other pledges in that auction and to the changes in the provisional price, and into three columns, depending on whether the resulting cumulative pledge is to sell, buy, or go back to zero. The percentages given are out of 55,611 pledges, in: 1052 first-position auctions, and 223,106 pledges in 982 sixth-position auctions.

involve a flip to the other side of the market, namely, rows I, K, and N. And those percentages of possibly contrarian strategies are higher for sixth-position auctions than for first-position auctions, although the first-position auctions should be more susceptible to deception. Especially for first-position auctions, many pledges bring the trader back to zero, more

Table 6
Styles of pledging during redbean auctions

Characteristics of pledge	First-position auctions				Sixth-position auctions			
	Seller	Buyer	Cancel	Total	Seller	Buyer	Cancel	Total
A. Only pledge, at initial provisional price	9.29	9.67	0.00	18.96	3.60	3.85	0.00	7.45
B. Only pledge, entered after initial price, and rational	4.44	4.59	0.00	9.03	1.09	1.16	0.00	2.24
C. Only pledge, entered after initial price, and irrational	1.84	1.65	0.00	3.49	0.53	0.59	0.00	1.12
D. First pledge of a sequence, at initial price	7.15	6.72	0.00	13.87	7.57	8.07	0.00	15.64
E. First pledge of a sequence, after initial price, and rational	2.61	2.64	0.00	5.25	1.01	1.03	0.00	2.05
F. First pledge of a sequence, after initial price, and irrational	1.84	1.71	0.00	3.55	0.64	0.68	0.00	1.32
G. Subsequent pledge, at same price, and larger	3.58	3.18	0.00	6.76	9.31	9.07	0.00	18.38
H. Subsequent pledge, at same price, and smaller	1.93	1.97	1.55	5.45	6.18	5.78	1.71	13.67
I. Subsequent pledge, at same price, and contrary	0.57	0.51	0.00	1.08	1.98	1.83	0.00	3.81
J. Subsequent pledge, at a later price, rational, and not contrary	7.94	8.07	8.01	24.03	9.10	9.19	3.23	21.52
K. Subsequent pledge, at a later price, rational, and contrary	1.02	0.96	0.00	1.99	1.28	1.32	0.00	2.60
L. Subsequent pledge, at a later price, irrational, and larger	2.16	1.99	0.00	4.16	3.06	2.95	0.00	6.02
M. Subsequent pledge, at a later price, irrational, and smaller	0.69	0.68	0.57	1.94	1.28	1.37	0.67	3.32
N. Subsequent pledge, at a later price, irrational, and contrary	0.20	0.25	0.00	0.45	0.46	0.42	0.00	0.88
Total	45.27	44.60	10.13	100.00	47.09	47.30	5.61	100.00

Every pledge is placed into fourteen rows, depending on its relationship to that trader's other pledges in that auction and to the changes in the provisional price, and into three columns, depending on whether the resulting cumulative pledge is to sell, buy, or go back to zero. The percentages given are out of 29,677 pledges in: 1634 first-position auctions, and 184,237 pledges in 1556 sixth-position auctions.

in number than those that cause a flip to the other side of the market. It is difficult to imagine either a contrarian strategy or an under-revelation strategy passing back through zero.

Also revealing about the prevalence of deceptive pledges are multiple pledges at the same provisional price. For example, in the auction in

Table 1, trader OC made five of his ultimate seven pledges at the initial provisional price, the last two of the five only a second apart, and in a sequence +10, −5, +5, +5, −5, ending where he began. In Table 5, for first-position corn, these subsequent four pledges are categorized as two instances in row G, namely, an increase in the cumulative pledge, and two instances in row H, namely, a decrease in the cumulative pledge, all in the column "Buyer" because the cumulative pledge remained positive throughout. Including these four pledges by OC, a large fraction of total pledges falls into rows G and H, and the related row I, ranging from 13.29% for first-position redbeans to 45.01% for sixth-position corn. Among these subsequent pledges at the same price, those increasing the cumulative pledge are only slightly more common than decreases (including cancellations and reversals). The most pronounced asymmetry is for sixth-position corn, for which row G is 23.30% versus the 21.82% representing the sum of rows H and I. If under-revelation were a common strategy, row G should be much higher than the sum of rows H and I.

Its initial provisional price being the one and only, the auction in Table 2 necessarily had instances of subsequent pledges at the same provisional price; indeed, 98 of the 150 pledges were subsequent pledges. For those 98 observations, Figure 2 plots the resulting cumulative pledge as a function of the previous cumulative pledge. Were many traders under-revealing, the slope in this relationship would be above 1.0, in inverse ratio to the average fragmentation of their true willingness to trade. Were large traders commonly pursuing a contrarian strategy, the relationship in Figure 2 would be cubic, with extreme observations in the second and fourth quadrants. Under the null hypothesis of no deceptive pledging, the relationship would be linear, the extreme observations in the first and third quadrants, and the slope 1.0. Figure 2 displays a markedly linear relationship, all extreme observations in the first and third quadrants, and an estimated slope of 0.99. Most other auctions with but one provisional price reveal much the same relationship, namely, one inconsistent with much deceptive pledging, at least of the two types surmised by economists to affect WTAs.[20]

Seemingly irrational pledges are usually explained by something other than deception, perhaps by the house trader anticipating the auctioneer's adjustments to the provisional price, or more probably, by the arrival of a real-time order from the FCM's customer. The TGE's records of the transactions at the equilibrium price for each FCM, those records available to us, distinguish its customers in the aggregate from its house account, and in each of these two accounts, distinguish buys from sells. (Each FCM's

[20] Among the 982 sixth-position corn auctions, 102 had a single provisional price. Among these 102, the slope coefficient is statistically insignificantly different from 1.0 in 62 instances, while in 36 instances, it appears to be below 1.0, and in only 4 instances, above 1.0. In 125 comparable redbean auctions, the slope coefficients are almost always 1.0 or below. A slope coefficient below 1.0 implies that some traders over-pledge initially.

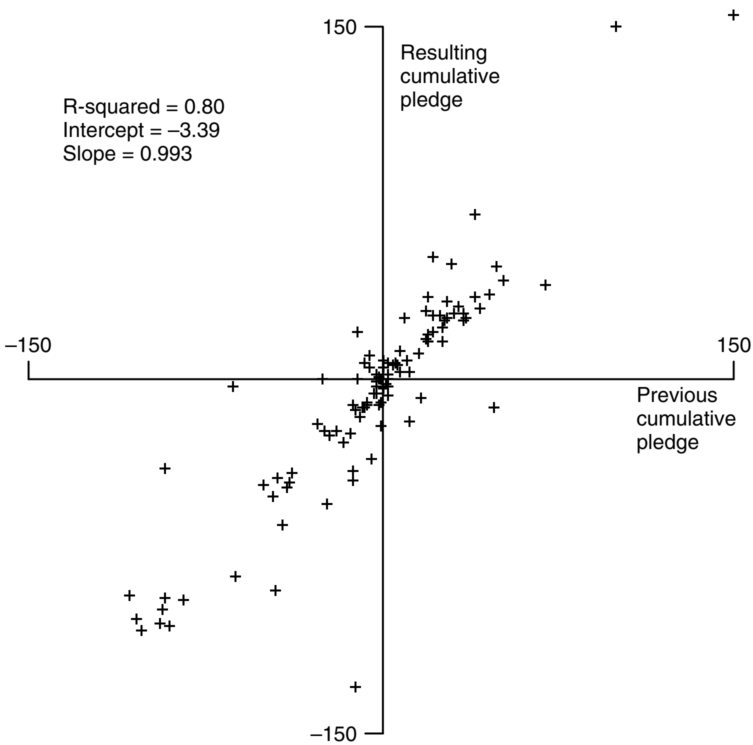

Figure 2
Modifications of cumulative pledges. Of the 150 pledges during the final auction for sixth-position corn on October 1, 1997, 98 pledges were modifications by 30 different traders. The auction equilibrated at the initial provisional price.

own records, unavailable to us, would distinguish each customer.) The transactions at the equilibrium price for the auction in Table 1 indicate that behind the 22 overt participants, there were at least 34 participants, because a number of the FCMs had more than one accounting entry for transactions. Trader OC, who flipped from +15 to −5 to conclude the auction in Table 1, represented a minimum of three parties, for its house account sold 5, its aggregate customer account sold 5 (probably only by one customer, given that 5 is a favored lot size), while its aggregate customer account also bought 5. Who was responsible for the five pledges at the initial provisional price, including the two that reversed each other within one second?[21] Who pursued the contrarian strategy at the auction's

[21] The transaction records indicate that trader KN's customer account bought 10 lots, while no customers sold and while the house account was inactive. Those 10 lots, which arrived in two pledges of 5, could be a single party fragmenting his true desire or two parties each wanting 5 and placing the order through KN at different times. Even when it is known that several parties were involved, as for OC, it is often difficult to disentangle the combined pledging sequence into logical strategies for individual traders.

end, OC's house account or a customer? If the house account, one of the victims of the deception was OC's own customers who wanted to buy. If a customer, that customer also had to deceive those at OC handling his orders, who probably had represented him before. No customer has the means of monitoring the orders of his FCM's other customers or the pledges of his FCM's house account, to determine whether his broker is helping or hurting his effort to deceive the whole market.

Even if deceptive pledging is not a major feature of TGE auctions, some pledging is known to be deceptive, at least in intent. When interviewed, the house trader for KY, one of the more active FCMs, boasted of deceptive pledging. (Much more often than most other traders, he cancels a cumulative pledge, even when ultimately trading; compared to his final pledge, he often pledges more initially, not less.) Other traders and TGE auctioneers interviewed all said they knew of KY's efforts, but regarded them as a nuisance to the speedy equilibration of the auctions. Obvious strategies should not deceive those playing the Walrasian "game" hour after hour, day after day.

To deceive others, traders on the TGE must act within the range of their normal behavior. Traders' frequency of pledging is quite consistent from auction to auction. For example, those traders who made only one pledge during a particular sixth-position redbean auction had made, in the immediately preceding fifth-position auction, no pledges 51.48% of the time, one pledge 25.79%, and more than seven pledges but 0.70%. Those traders most active in a sixth-position redbean auction, making more than seven pledges, were likely among the active participants in the preceding fifth-position auction: 26.28% of the time they had pledged more than seven times, 57.81% more than three times, and only 9.16% not at all. Similar consistency in behavior is found across longer spans of time too, and across commodities. For example, OC is almost always among the most active traders whatever the position or commodity. A habit by OC of contrarian pledging through "take all remaining" would presumably long since has been noticed by others and factored into their own pledging behavior.

The median number of pledges by a trader in sixth-position auctions, whether corn or redbeans, is 2, whereas the median number of provisional prices is 5. That is, traders do not respond to every provisional price. Many traders, as implied by Tables 5 and 6, make but one pledge, and at the initial provisional price. Such pledges are the equivalent of "market orders" in continuous markets. Not only are such market orders not deceptive in themselves, they presume others will not exploit them.

4. The Dispersion of Information Across Auction Participants

In addition to the TGE auctions' transparency, the importance of which has been emphasized by Pagano and Roell (1996), *itayose* offers another advantage for price formation. Although in continuous futures markets all delivery months can be traded simultaneously, a delivery month's price formation on the TGE is partly isolated from the processes of related contracts, because delivery months are considered in sequence. But the sequence within a session itself reveals information. In other words, traders and the auctioneer should have more accurate beliefs about the next equilibrium after observing the equilibria of related contracts auctioned moments before.

Evidence related to the dispersion of information can be seen in Table 3. For both commodities, the average number of provisional price changes required to reach equilibrium does not increase with the position, even though pledging activity increases substantially. For example, auctions for sixth-position corn experience nearly 9 times the volume of first-position corn and have nearly 3 times the number of traders participating on average, yet conclude in close to the same number of seconds. Table 3 also suggests that the auctioneer's ability to forecast when an auction is near equilibrium improves as the session progresses. Presumably, the better the auctioneer is at predicting the final price, the closer the provisional price will be to the final price when he first posts "OK". The percentage in the row labeled "Percentage of price changes after first OK" decreases with position. This pattern is present even in the percentage of an auction's length that elapses after "OK" was first indicated.

The relative information structures of corn and redbeans provide another natural comparison regarding the dispersion of information. The TGE's corn futures contract is nearly identical to the Chicago Board of Trade's, differing only in delivery location [Holder, Pace, and Tomas (2002)]. The redbean futures market operates only through the TGE. Redbeans are marketed in Japan primarily by a few farmer cooperatives, which hide supply information. These cooperatives and other large handlers of redbeans are typically represented by just a few FCMs. Thus, the degree of information asymmetry across auction participants is presumably greater for redbean auctions compared to corn auctions.[22] Several statistics in Table 3 accord with this presumptive difference in information asymmetry. Nearly 40 traders, on average, participate in any corn auction (daily volume is nearly two-thirds that on the CBOT), about twice the average number of participants in redbean auctions, yet the corn auctions take only slightly longer.

[22] In equity markets, the presence of privately informed investors create illiquidity costs for uniformed investors [Brennan and Subrahmanyam (1996)], which result in a measurably lower price [Easley, Hvidkjaer, and O'Hara (2002)]. Such direct effects on price are unlikely to apply to the TGE's futures markets. Speculators in corn and redbeans may be uniformed, but they are on both sides of the market and need not be present at all. Both markets have considerable volume, as can be seen in Table 3, and should not display the characteristic bias of thin futures markets [Gray (1960)]. Anyone who trades the most liquid sixth-position contract knows it will become, in turn, fifth-position, fourth-position, and so on, to the least liquid first-position.

Direct evidence that the auctioneer's and traders' uncertainty about the equilibrium value of contracts decreases during the course of a session can be obtained by employing a method similar to one used by Biais, Hillion, and Spatt (1999) to measure the informational content of indicative prices set during the preopening at the Paris Bourse. If the TGE auctioneer and traders are becoming more certain about the value of futures contracts, the provisional price displayed during auctions conducted later in a session (auctions for later positions) should be a better predictor of the futures contracts' equilibrium value compared to the provisional prices of auctions conducted earlier in a session. In practice, this measurement requires disaggregating corn and redbean auctions by the position of the futures contract and across each second, t, estimating

$$dp_{f,a} = \alpha + \beta_t dp_{t,a} + \gamma_t (dp_{t,a} * OK_t) + \varepsilon_t \tag{1}$$

where $dp_{f,a}$ is the change in a contract's final price between auction $a-1$ and a and $dp_{t,a}$ is the change in a contract's provisional price between the final price reached in auction $a-1$ and the provisional price displayed at second t of auction a. If traders and the auctioneer are, in fact, learning during an auction, the coefficients of Equation (1) will be nonstationary and the nonstationarity should be accounted for by estimating one OLS regression for each second, and for each position.

In Table 7, we report the R^2 rather than the coefficients resulting from regression (1) for each of 15 moments 6 seconds apart across each position of corn and redbean auctions. For all positions and both commodities, the R^2 quickly approaches 1.00, an indication that provisional prices and thus pledges are largely informative.[23] Table 7 also shows that the provisional price aggregates information more quickly during corn auctions and more quickly during auctions for later positions, consistent with the likely dispersion of information. These results are also evidence that provisional prices sufficiently discipline traders to make informative pledges. If traders respond deceptively to provisional prices, provisional prices should be largely noise.

The first row of Table 7 implies something most important about the dynamics of WTAs. The high R^2 as of the first second, say of 0.95 for sixth-position redbean contracts, is a statistical vocabulary for saying that the auctioneer makes a good initial guess for the final price, having seen the

[23] The low R^2 of the regression for the first interval of the first-position auctions is explained by the TGE rule that instructs the auctioneer to set the first provisional price of first-position auctions to the price reached in the previous session. Were the auctioneer allowed to use even the information implicit in the price changes in the previous session's auctions for the second- through sixth-position auctions, that R^2 would be at least 0.20.

Table 7
Informational content of changes in provisional price

	Position of corn futures contract						Position of redbean futures contract					
Second	1st	2nd	3rd	4th	5th	6th	1st	2nd	3rd	4th	5th	6th
1	0.00	0.63	0.84	0.89	0.88	0.89	0.00	0.30	0.46	0.63	0.58	0.67
6	0.00	0.63	0.84	0.89	0.88	0.89	0.00	0.30	0.46	0.63	0.58	0.67
12	0.13	0.63	0.84	0.89	0.88	0.89	0.17	0.33	0.47	0.64	0.59	0.67
18	0.46	0.68	0.85	**0.90**	0.89	**0.90**	0.50	0.43	0.51	0.67	0.62	0.69
24	0.62	0.74	0.88	0.91	**0.91**	0.91	0.63	0.55	0.58	0.72	0.68	0.74
30	0.69	0.80	**0.90**	0.93	0.93	0.92	0.72	0.65	0.67	0.78	0.75	0.78
36	0.73	0.85	0.92	0.94	0.94	0.94	0.77	0.74	0.74	0.83	0.81	0.82
42	0.77	0.88	0.94	0.95	0.96	0.95	0.79	0.80	0.80	0.87	0.86	0.86
48	0.80	**0.91**	0.95	0.96	0.97	0.96	0.82	0.85	0.85	**0.90**	0.89	0.88
54	0.83	0.93	0.96	0.97	0.97	0.97	0.85	0.88	0.89	0.92	**0.92**	**0.90**
60	0.86	0.95	0.97	0.98	0.98	0.97	0.87	**0.90**	**0.91**	0.94	0.94	0.92
66	0.88	0.96	0.98	0.98	0.98	0.97	0.89	0.92	0.93	0.95	0.95	0.93
72	**0.90**	0.96	0.98	0.98	0.98	0.98	**0.91**	0.93	0.94	0.95	0.96	0.95
78	0.92	0.97	0.98	0.98	0.98	0.98	0.92	0.95	0.95	0.96	0.96	0.95
84	0.93	0.98	0.98	0.98	0.98	0.98	0.93	0.96	0.96	0.96	0.97	0.96
90	0.94	0.98	0.98	0.98	0.99	0.98	0.94	0.97	0.97	0.96	0.97	0.96

The table reports the R^2 resulting from estimating:

$$dp_{f,a} = \alpha + \beta_t dp_{t,a} + \gamma_t (dp_{t,a} * OK_t) + \varepsilon_t$$

where $dp_{f,a}$ is the return in a contract's final price between session a and $a-1$ and $dp_{t,a}$ is the return in a contract's provisional price displayed as of second t of an auction for a contract during session a and the final price reached in session $a-1$. OK_t is a dummy variable indicating if the OK sign was ever posted prior to second t. To highlight increases in the informational content of changes in the provisional price, in bold is the first R^2 of each column that is at least 0.90. To be included, the auctions had to last at least 60 seconds but no more than 180 seconds. The smallest number of auctions included is 634, for 5th-position corn.

price changes in the auctions already conducted during that session.[24] The traders too start the sixth-position auctions with knowledge of the auctions already conducted that session. Even if the time between TGE corn sessions were to shrink from 2 hours, to 1 hour, to 15 minutes, some of the impact of the sequential trading of the six futures contracts would be preserved and so a large part of the dynamics would be in the jumps between one final price and the next first provisional price, reflecting the intervening auctions for other positions. One could imagine a rule constraining the auctioneer to start each auction with the previous final price, as does the TGE's rule for the first-position, but no rule will remove the traders' knowledge of intervening auctions' equilibrium prices.[25] Traders would have only more

[24] Not surprisingly, the price change for the fifth-position auction alone correlates highly, 0.76, with the change in the first provisional price for the sixth-position auction from the equilibrium price at the previous session.

[25] Corn traders and the auctioneer also know what happened during the CBOT's hours of trading, which transpire overnight Tokyo time. As noted before, the first-position corn auction at the 9:00 A.M. session averages a high number of changes in the provisional price. When the CBOT has moved substantially, the TGE auctioneer, although starting at the previous day's final price on the TGE, moves quickly through provisional prices.

reason to enter pledges without regard to that beginning provisional price but in anticipation of the auctioneer's likely adjustments.

5. A VAR Representation of TGE Auctions

Comparing equities traded on the Tel Aviv Stock Exchange through call markets to those traded continuously, Kalay, Wei, and Wohl (2002) estimate the call mechanism for lower-capitalized firms to depress their prices some 5%.[26] Five percent of the price of corn in Tokyo corresponds to one-third the ocean freight rate from the United States, much too large to be plausible. More generally, futures contracts are tied into webs of spatial and temporal arbitrage. The TGE's corn and redbean futures prices align closely with prices in other markets. Thus, the *itayose* mechanism can be considered as affecting the short-run dynamics of price formation, rather than the long-run averages.

Impulse response functions derived from VAR coefficients have been used extensively to study short-run dynamics during continuous auctions. For example, Hasbrouck (1991) used them to show that the impact of a trade on the NYSE is persistent and dependant on trade size, suggesting that trades are informative and that larger trades are correlated with the arrival of information.[27] If provisional prices on the TGE do not sufficiently discipline traders to pledge sensibly, the estimated impact of a pledge should be low and the VAR structure of TGE auctions should differ from those of continuous auctions.

Hasbrouck's approach suggests a VAR representation of the TGE auctions should allow for the possibility of nonlinear effects from excess-demand. Hence, we represent change in excess-demand and revision to the provisional price within TGE auctions as VAR System (2):

$$\begin{aligned} dp_{a,t} &= \alpha + \sum_{i=1}^{10} \beta_i^1 dp_{a,t-i} + \sum_{i=1}^{10} \beta_i^2 dExD_{a,t-i} + \sum_{i=1}^{10} \beta_i^3 dExD_{a,t-i}^2 \\ &\quad + \sum_{j=4}^{6} \sum_{i=1}^{10} \beta_i^j \delta_j (dp_{a,t-i} + dExD_{a,t-i}) + v1_{a,t} \end{aligned}$$

[26] Muscarella and Piwowar (2001) find an effect of similar magnitude among equities transferred between call and continuous trading on the Paris Bourse.

[27] Engle and Patton (2004) and Pascual, Escribano, and Tapia (2004) also employ VAR to study price formation on the NYSE. These studies are concerned with intraday liquidity dynamics, in contrast to interday dynamics, such as in the study of the NYSE by Chordia, Sarkar, and Subrahmanyam (2005).

$$dExD_{a,t} = \alpha + \sum_{i=0}^{10} \gamma_i^1 dp_{a,t-i} + \sum_{i=1}^{10} \gamma_i^2 dExD_{a,t-i} + \sum_{i=1}^{10} \gamma_i^3 dExD_{a,t-i}^2 + \sum_{j=4}^{6} \sum_{i=1}^{10} \gamma_i^j \delta_j (dp_{a,t-i} + dExD_{a,t-i}) + \upsilon 2_{a,t}$$

where $dp_{a,t}$ is the provisional price revision at second t of auction a, $dExD_{a,t}$ is the change in excess-demand, $dExD_{a,t}^2$ is the change in the signed squared excess-demand, and α is a vector of ones. Lags of $dExD_{a,t}$ and $dp_{a,t}$ interact with two additional variables. One, δ_1, equals 1.0 if the OK sign was on at second t and 0.0 otherwise. To account for the possibility that the dynamics are sensitive to time, δ_2 equals 1.0 if second t falls within the first 30 seconds of the auction and 0.0 otherwise. The inclusion of these two interaction terms allows a test of whether a pledge's price impact is sensitive to the uncertainty about the eventual final price.[28]

It is possible that the dynamics will be sensitive to whether excess-demand is positive or negative. It is also possible that the auctioneer and traders' sensitivity to the excess-demand may be a function of the total level of pledge flow. Therefore, we estimated two alternative specifications to VAR System (2). The first disaggregated the excess-demand variable into total contracts pledged to buy and total contracts pledged to sell. We found no disproportionate sensitivity to whether the pledge was a buy or a sell.[29] For the second alternative model, we generated a variable equal to the excess-demand at second t divided by the total pledge flow observed during the auction. We interacted this variable with the excess-demand and included lags of the interaction term as an exogenous variable in System (2). However, an F-test did not reject the hypothesis that all coefficients of the lags of this interactive variable equal zero.

For our VAR estimates, we dropped those auctions that lasted less than 60 seconds.[30] We also dropped the first 7 to 9 seconds of each auction, depending on the position, since it takes about that long for most traders to react to the initial provisional price. Even though a further ten observations were lost from each auction due to the lags, the minimum number of observations was 45,368 for third-position corn, contributed by 754 auctions. The maximum was 82,703 observations, contributed by

[28] We expected the OK sign itself to be the third component of a three-equation VAR, but the coefficients and input response function of the other two variables were not much different. Perhaps VAR represents less well a 0–1 variable such as the OK sign.

[29] Further, the forecast accuracy of this alternative was lower than that of VAR System (2).

[30] Because of the special qualities of the first-position corn auction at the first session of the day, we did not use those auctions. None of these exclusions matters to the conclusions from the VAR analysis, although they do matter to the particular estimated coefficients.

1300 sixth-position redbean auctions. We found that estimating System (2) with a longer lag had no material impact.[31]

The estimating procedure for VAR System (2), although using many auctions for a particular futures position, treats each auction as interchangeable within the total number of observations. Possibly, the behavior in the immediately preceding auctions influences the behavior within a particular auction. If so, the estimating procedure should take advantage of such serial connections. We conducted a number of tests for such serial connections broadly defined. We found none. The average absolute residual for the provisional price series in System (2) is only faintly related to the average absolute residual in the previous session's auction for that position or to the average absolute residual for auctions earlier that same session. The initial provisional prices in each auction evidently express previous auctions, as suggested by Table 7.

6. Implications of the VAR Estimates

In the manner of Hasbrouck's (1991) measure of the price impact of a trade on the NYSE, we calculated the impact of a pledge on the provisional price by iterating on the estimated equations in VAR System (2) and accumulating across each second the provisional price change estimated to be induced by a shock to excess-demand. Because the pattern of the impact second by second is similar across all positions and across the first-30-seconds/after-30-seconds split in the auction, Figure 3 plots the cumulative impact for only one combination. Figure 3 illustrates the point estimate and 95% confidence bands of a 50-contract shock's impact on the provisional price during sixth-position corn auctions while the OK sign is off during the first 30 seconds.

As is apparent in Figure 3, the provisional price responds to an excess-demand shock only gradually. It takes some 60 seconds for the provisional price to react nearly fully to the pledge, some 15 seconds for even 50% of the cumulative price impact. Further, a 50-contract shock has a permanent impact on the provisional price −2.80 yen for these sixth-position corn auctions—an indication that pledges are not only serious but also informative. The middle of TGE auctions is indistinguishable from the midday of dealer-dominated markets.

Figure 4, for corn on the left and for redbeans on the right, reports in panel A for each futures position the cumulative impact on the provisional price after a shock to excess-demand of the average-sized pledge for that

[31] The recursive structure of System (2) assumes that the current provisional price change effects the current change in excess-demand while the current change in excess-demand does not impact the current provisional price change. Our choice of this recursive structure was motivated by the human capability to react within one second. Because VAR results are often sensitive to the recursive structure, we also tried reversing it.

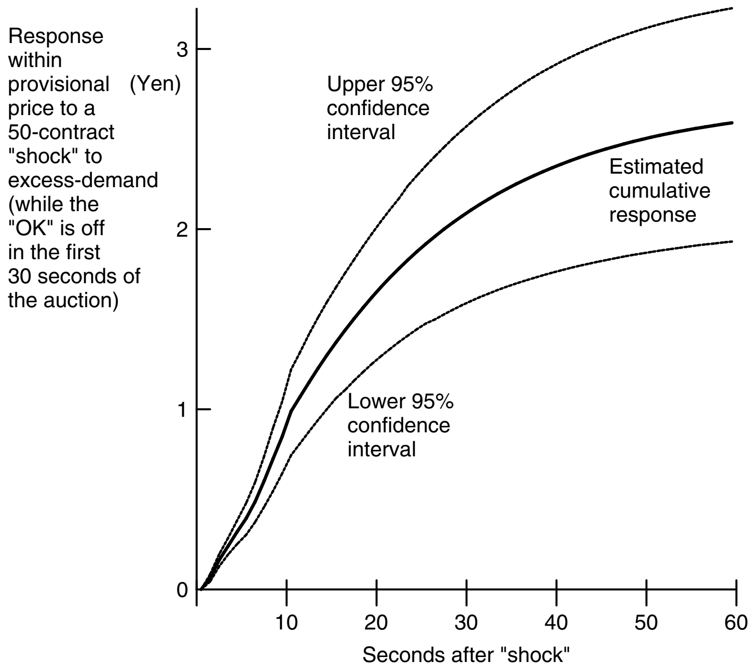

Figure 3
Impulse and cumulative responses within the provisional price series from a shock to excess-demand. Calculated for sixth-position corn contracts, as implied by the estimated coefficients from VAR System (2).

position, under four cases: the shock occurred during the first 30 seconds of an auction when the OK sign was off; during the first 30 seconds of an auction when the OK sign was on; after the first 30 seconds when the OK sign is off; and after 30 seconds when the OK sign was on. The differences across contract position are as one would expect. Because the average pledge size, not to mention the number of traders, increases with the position, the impact on the provisional price of a shock of the same size would be even lower for the more distant positions. For all corn and redbean positions, the price impact is less after the first 30 seconds than earlier. Less clear is the effect of the OK sign on the price impact. Usually there is a bigger price impact if "OK" is on at the moment of the shock, especially if "OK" is on during the first 30 seconds of an auction. After the first 30 seconds, the "OK" seems to have little or no influence on the price impact of shock to excess-demand during corn auctions, where information is relatively more dispersed.

The differences in price impact from a pledge—equivalently its informational content—across positions accord with several market-microstructure theories. For instance, Admati and Pfleiderer (1988) predict

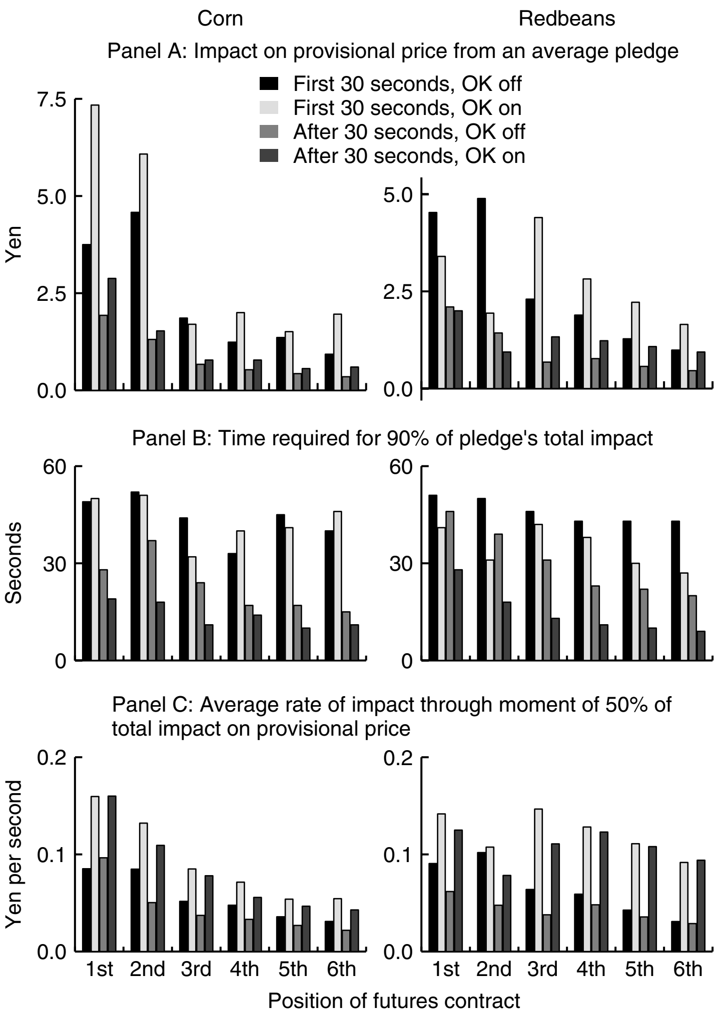

Figure 4
Impact on the provisional price from a shock to excess-demand. Calculated for each commodity and position, as implied by the estimated coefficients from VAR System (2).

that when traders observe similar information signals, individual orders should offer relatively little to the existing pool of information, such as the prevailing provisional price on the TGE. Vives (1995) predicts that as the uncertainty surrounding the value of the asset diminishes: (1) provisional prices become increasingly informative and the auctioneer's pricing rule becomes decreasingly sensitive to pledge flow; (2) the increased depth induces informed traders to respond more intensely to their private information and so pledges become more informative; and (3) the effect of the auctioneer's learning dominates the effect of more informative pledges and thus the net effect is that depth increases.[32] Subrahmanyam (1991) predicts that when information is more nearly evenly dispersed across traders, the resulting increased competition would cause prices to aggregate the private information more quickly.

At first glance, the differences in depth when the OK sign is on or off or when the auction has just begun or has lasted longer may seem to provide an astute trader profitable opportunities through deceptive pledges. Seemingly, a trader who wants to buy 50 lots could, early in the auction, pledge to sell 100 lots and later in the auction pledge to buy 150 lots, the two pledges together having a smaller price impact then an early honest pledge. Several factors work against such strategies, however. First, all the estimated coefficients for the quadratic terms in VAR System (2) are small, usually statistically insignificant, and have no material effect on the cumulative impact of an imbalance shock. Second, such strategies are risky. A trader cannot presume that "OK" will be on during the first 30 seconds nor that it will be off any time later. A trader can be certain of placing a pledge in the first 30 seconds with "OK" off, because that is how an auction commences, and he could be poised for a later pledge at the first instant of the auctioneer's OK sign, his finger over the enter button. But even that certain approach runs up against the third factor: The smaller price impact later in auctions is felt at a faster rate.

The dynamic aspect of the price impact is seen in Figure 4 panel B, which plots the number of seconds it takes each position's provisional price to reach 90% of the eventual total adjustment following a shock to excess-demand. Panel C shows the average rate through 50% of the price impact. For both corn and redbeans, provisional prices embody information more rapidly during the second part of an auction compared to the first 30 seconds. For both commodities and nearly all positions, the provisional price adjusts at a faster rate when the OK sign is on. In sum, when the auctioneer is more certain about the equilibrium price of an auction and increases the risk of the auction ending, the provisional price adjusts more rapidly to the information contained in pledges.

The difficulty for deceptive pledging caused by more rapid price impacts later in the auction can be seen with the help of Figure 3 for a 50-lot shock, with a second impulse response function superimposed. If the trader pledged to buy 50 early in the auction, say at second 20, by second 45 in the auction, 25 seconds later, the price impact implied by the impulse response function would have accumulated to 2.10 yen, 76% out of the prospective total of 2.80. If the trader waited past the first 30 seconds,

[32] Another interpretation of a decrease in information asymmetry offered by Admati and Pfleiderer (1988) is that as the number of informed traders increases and if the informed traders' signals are highly correlated, as TGE traders' signals would be if the signals were a result of watching previous auctions equilibrate.

indeed until the OK first came on, say at second 35, the cumulative price impact over the 10 seconds until second 45 would be 90% of the total, namely 1.54. If the auction ended at second 45, it would be much less obvious that pledging late is superior to pledging early, especially if the respective confidence intervals are considered. Clearly, a strategy of late pledges would be preferred, provided the later pledge had a slower impact as well as a smaller one and provided the auction could not end suddenly.

The results reported in Figure 4 are not only useful for understanding the effect of information dispersion on depth but are also instructive about liquidity itself. Although the definition of liquidity varies across studies, increasingly the market-microstructure literature has emphasized its dynamic aspect. For instance, Dufour and Engle (2000) define a market as liquid if a trade's impact on price is relatively small and if price adjusts relatively slowly. On the TGE, while the magnitude of a pledge's impact on the provisional price decreases with the position and the time elapsed during an auction, the speed at which the provisional price adjusts to a pledge increases, seemingly contradicting this definition of liquidity. Such a relationship must hold on the TGE, or the *itayose* mechanism would be susceptible to deceptive pledging.

7. Conclusion

In experimental WTAs involving ten players and a variety of rules about players' strategies and differences in their knowledge of aggregate excess-demand, Bronfman et al. (1996) found all their versions to be less efficient than continuous double auction markets. Evidently, players in experimental WTAs pledge deceptively, because nothing in the auction is binding until it is over. Bronfman et al. (p. 697) wondered whether a WTA would work better "in field applications because it uses a live auctioneer who is better informed and more flexible than a computer algorithm," as in their experiment.

Conducted by live auctioneers, the TGE's WTAs do work well. The success of the *itayose* mechanism for price formation is, nevertheless, more likely due to institutional features not emphasized during the design of experimental markets or in theoretical constructs. TGE auctioneers make extensive use of an "OK" sign, which indicates the auctioneer believes an equilibrium is near and which allows any new pledge balancing excess-demand to end the auction at that instant. The TGE auctioneers' timing of the OK sign may not discourage all deception but it is surely more effective than Bronfman et al.'s "soft close" of allowing any pledge to be revised should the market balance. TGE auctioneers adjust the provisional price not in proportion to excess-demand, but only one tick at a time, which institutional feature dampens the incentive to pledge deceptively and which reduces backtracking.[33] TGE auctioneers are not constrained to adjust the provisional price as a metronome, but judge traders' inclinations to pledge, sometimes changing the provisional price quickly and other times slowly. In contrast to auctioneers' central role on the TGE, auctioneers are not even present in theoretical models emphasizing the strategic game within WTAs [e.g., Dubey, Mas-Colell, and Shubik (1980)].

Likewise, the 80 possible direct traders in TGE auctions face subtly different rules and informational transparency than considered in any theoretical construct or experimental design. TGE traders need not and do not all place pledges in response to the auctioneer's first few provisional prices. Because a pledge remains valid at a new provisional price unless adjusted, TGE traders must pay attention. TGE traders often adjust their pledges while the same provisional price applies. TGE traders may and do flip from pledging to buy to pledging to sell. TGE traders sometimes pledge in anticipation of a price the auctioneer will propose. Some TGE traders attempt to deceive others, but they cannot have much hope, because they have been observed in thousands of auctions. Each TGE trader's pledge is instantly visible to everyone. Not visible, however, is the composition of the customers behind each trader's pledge. In other words, TGE auctions primarily involve brokers, whose strategies must differ from those their customers might follow if everyone were a direct participant.

Because of all these lags, anticipations, and interactions observed on the TGE, WTAs do not resemble economists' perception of how prices form in them. The relationship between a WTA's provisional prices and pledges is more appropriately modeled as a dynamic system. We find that the dynamics of WTAs share many characteristics with the dynamics of continuous double auctions. Provisional price changes are positively related to changes in excess-demand, just as changes in excess-demand have a permanent impact on the provisional price and hence on the equilibrium price. Provisional prices incorporate the information revealed in a pledge gradually. Pledging in TGE auctions is most intense during the early portion of auctions after which time its frequency drops substantially. This flow of pledges is consistent with theoretical predictions that assume traders behave competitively [Vives (1995)]. Around 60% of all pledges entered during the first few seconds of auctions are modified but most modifications can be rationalized by the corresponding change to the provisional price. These patterns suggest that the vast majority of pledges are not deceptive.

Because futures contracts are auctioned on the TGE by maturity in a standard sequence, known as a session, information about the particular

[33] In a recent experiment, in which the WTA performed better than previously, Pouget (2004) limited the price change to one (relatively large) tick no matter the size of the imbalance. But the design also restricted traders to trade zero or one unit, which discreteness itself limits deception.

commodity naturally becomes more evenly dispersed across traders as a session progresses. In particular, the auctioneer and traders employ knowledge of closely related auctions for the start of each auction. We find that even during the early seconds of an auction, provisional prices predict well the final price, and are even more informative as the session progresses. Although provisional prices aggregate information more quickly during corn auctions than in redbean auctions, the rate that information is aggregated is high for both, contrary to what would be expected if the nonbinding provisional price were not disciplining traders to pledge sensibly.

On the TGE, not only does information become more evenly dispersed during a session of auctions but also during the course of any one auction, inasmuch as WTAs induce disclosure of private information before any trades are allowed to take place. Consistent with the market-microstructure theory of continuous auctions, we find that the depth of TGE auctions is higher when information becomes more dispersed across traders. Yet, as a typical auction progresses, the speed at which the provisional price adjusts to an excess-demand shock also increases, a property inconsistent with the common definition of liquidity in continuous auctions but likely in WTAs that could end at any moment.

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