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DIFFERENT LEVELS OF NONCOOPERATIVE TACIT COLLUSION: AN EMPIRICAL TEST

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This paper tests for the existence of different levels of noncooperative tacit collusion by exploiting almost same game environments of two markets, Dallas-Ft. Worth school milk market and San Antonio school milk market. The comparison of bidding strategies, bidding patterns over the bid season, average winning bids, and the incumbency premium in the DFW market with those in the San Antonio market verifies that different equilibria in the form of different levels of noncooperative tacit collusion can be supported in same game environments.

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I. INTRODUCTION

Through careful statistical analysis of dairy companies bidding behaviors in Dallas-Ft. Worth school milk market, Lee(1998a) shows that cooperation based on rationality and repetition satisfies the conditions for a kind of Folk Theorem. Fairly strict tit-for-tat strategies actually keep firms from defecting and maintain stability in market share dispersion among firms over time, and thus raise prices far in excess of the competitive level. No defection in the early stages of the game and statistically significant price shading at the end of bid season turn out to be equilibrium outcomes in finitely repeated game.[1] This solid evidence is

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[1] With a fixed finite horizon, "always defect" is the only subgame-perfect-equlibrium outcome because the scheme of self-reinforcing rewards and punishments used in the Folk Theorem can

considerably consistent with the intuitive idea of Folk Theorem in the case of milk contractors game. The Dallas-Ft. Worth school milk data also strongly suggests that all major milk processors are engaged in complementary bidding to allocate consumers geographically and command statistically significant incumbency premia in their incumbent districts.[2] The statistical evidence verifies the existence of so-called conscious parallelism that a firm tends to submit relatively high bids in districts in which rival firms win repeatedly, hoping that rival firms would submit relatively high bids in his incumbent districts. This behavior makes complementary bidding patterns observable. Price shading and higher returns in the incumbent districts turn out to be not simply cost effects due to having served a district before.

This paper tests for the existence of different levels of noncooperative tacit collusion by exploiting almost same game environments of two markets, Dallas-Ft. Worth and San Antonio school milk market.[3] The principal suppliers of the DFW school milk market during the sample period 1980-1992 were Borden, Cabell, Foremost, Oak Farms, Preston, Schepps, and Vandervoort. The major suppliers of San Antonio during the sample period 1980-1991 were Borden, Foremost, Oak Farms, Preston, Schepps, and Vandervoort. Only Cabell is missing in the players list in the San Antonio market. Similar players and

unravel backward from the terminal date. However, there have been many experimental studies of games in which the participants are indeed told that the horizon has been set at a fixed finite point, and there is a unique stage-game equilibrium. In such experimental studies of the Prisoner's Dilemma, players do in fact cooperate in many periods, despite what backward induction predicts. In contrast to the naive backward induction argument, ε-equilibrium of Radner (1980, 1986) and finite automata of Kreps, Milgrom, Roberts, and Wilson (1982) have shown that under quite general conditions a kind of Folk Theorem emerges in the finitely repeated game context. The results of these two papers remove the dichotomy between the finitely and the infinitely repeated game. These two approaches explain the features of the School milk contractors game in many aspects quite well. The finitely repeated game environment of Kreps et al. (1982) fits the characteristics of school milk contractors game far better than the finitely repeated game setting of Radner (1980, 1986), with an exception of approximate rationality that players neglect small mistakes. There are two extensions of their game model to reflect school milk contractors game properly. One extension is that all perturbations are allowed. Each of the players may pretend to be a different automaton, in favor of his own interest. The other is that small mistakes may be ignored.

[2] Lanzillotti(1996) examines extensively various dairy companies allocation schemes of school milk contracts using signaling, sham bids to honor incumbency and other devices to determine whether bidding was collusive or pure oligopolistic interdependent behavior following noncooperative game theory.

[3] When we study games that are repeated a large but finite number of times, the set of expected average payoff allocations that are achievable in sequential equilibrium may or mat not be smaller than the set of that is achievable in equilibrium of the corresponding infinitely repeated game. Fudenberg and Maskin (1986) have shown, under some weak assumptions, that any payoff allocation that is achievable in the infinitely repeated game, according to the general feasibility theorem, may also be approximately achievable as an expected average payoff allocation in a sequential equilibrium of long finitely repeated version of the game with small probability perturbations.

cost structures in both markets seem to be natural settings for testing different equilibria between markets. The firms in each market are supposed to cooperate to reach an equilibrium that yields a pareto-optimal point in the set of the firms equilibrium profile. The comparison of bidding strategies, bidding patterns over the bid season, average winning bids, and the incumbency premium in the DFW market with those in the San Antonio market verifies that different equilibria in the form of different levels of noncooperative tacit collusion can be supported in same game environments. This empirical study overcomes the problem of the inaccessibility of relevant data about a game environment, which is a major problem of an empirical study of repeated games. In comparison with experimental studies in which the objective is to examine behavior conditional on a controlled environment, this empirical study has the advantage that this micro data pertain to practical situations in which the stakes are large and the participants are skilled and experienced.

The rest of the paper is organized as follows. Section II illustrates the research motive of the paper. Section III explains the market background and data. Section IV describes an empirical model. Section V examines test results. This paper ends with concluding remarks in section VI.

Ⅱ. RESEARCH MOTIVE

Hewitt, McClave, and Sibley (1993) provide statistical evidence that DFW school milk prices were three to four cents per half pint above San Antonio school milk price.[4] This gap translated into 18 percent differential in average milk prices may be a cooperative outcome in noncooperative environment.[5] However, it is noteworthy that school milk prices were higher in the San Antonio market than in the repeatedly bid-rigged Florida market in the 1980s, even though there was substantial cost advantage in the San Antonio market.[6]

[4] The composite cost of living index is about six percent higher in DFW than in San Antonio. An index of transportation costs shows roughly a ten percent difference. They conclude that if all costs apart from raw milk are assumed to be 10 percent higher in DFW than in San Antonio, then the cost difference between DFW and San Antonio is roughly 1.96 percent, far lower than the 18% difference between school milk prices.

[5] Since school milk bid meeting occurs at interval over a four or five month period, repeated each year, it would not be surprising to conclude that the observed pattern of complementary bidding and high incumbency rates could be a Nash equilibrium sustained by punishment strategies.

[6] According to a list of criminal cases filed by the antitrust division involving the milk industry, 25 bid rigging cases for school milk were filed in Florida. The milk processors were engaged in overt collusion by rotating bidding, where a winner is chosen in advance. In all Florida cases the defendant pleaded guilty and the ten firms accused of colluding in Florida paid a total of about $15 million (not counting civil cases) in fines. Fourteen persons were sentenced for a total of 7.3 years in prison.

[Table 1] Cost of Living Index (US Average = 100)

	Composite Living index		Transportation Cost	
Year	Miami	San Antonio	Miami	San Antonio
81	101.7	98.3	95.3	104.4
82	102.7	97.8	96.7	99.9
83	105.4	99.1	111.6	101.4
84	109.1	100.8	108.5	100.8
85	111.7	99.2	104.8	104.6
86	110.3	98.5	95.2	99.7
87	112.4	98.2	107.1	101.1
88	108.6	100.5	103.7	103.3
89	110.1	97.1	99.6	98.4
90	110.3	97.1	106.1	101.3

Source: Cost of Living Index: Inter-City Cost of Living Indicators, published by American Chamber of Commerce Researchers Association.

The average winning bids of all milk types for 1980-1989 was 13.51 cents in constant 1982 dollars in the San Antonio market, and it was 13.26 cents in constant 1982 dollars in the Florida market. The raw milk accounts for between 60 and 70% of the delivered cost of a half pint of milk. Its pricing follows a base-point pricing; the Minnesota/Wisconsin price plus a fixed differential typically increasing in distance from the upper Midwest. A comparison of the raw milk price in constant 1982 dollars between Miami and San Antonio during the same sample period reveals that the two prices follow a very similar pattern but the raw milk price in Miami is about 17 percent higher.[7] This difference is attributed to the longer distance from Minnesota/Wisconsin. A milk industry rule of thumb is that delivery costs are about 6 cents per gallon, or under .4 cents per half pint; this is about three percent of average San Antonio winning bids (in constant 1982 dollars) of all milk types during 1980-1989.

An index of transportation costs in Table 1 shows that the delivery cost is one percent higher in Miami. I have no comparable payroll data between San Antonio and Miami for the dairies and therefore count on examining cost of living indices, on the assumption that they correlate well with labor costs. The composite cost of living index indicates that it is ten percent higher in Miami than in San Antonio. If all costs except raw milk are assumed to be ten percent higher in Miami than in San Antonio, the cost difference between San Antonio and Miami is roughly 8.64 percent, still leaving the delivered cost

[7] This price differential is calculated on the basis of Federal Milk Marketing Order Class 1 minimum raw milk prices.

lower in San Antonio. By the same method, when we can compare the delivered costs in San Antonio and Tampa, another major city on the west coast of Florida, the cost difference between San Antonio and Tampa is roughly 8.18 percent, still leaving the delivered cost lower in San Antonio.[8] This statistical comparisons suggest that same major milk processors in San Antonio as well as in Dallas-Ft. Worth might enjoy supra competitive profits by same noncooperative tacit collusion, complementary bidding strategy, and incumbency premium.

Ⅲ. MARKET BACKGROUND AND DATA

A. Market Background

One-year school milk contracts are awarded following a first-price sealed-bid auction. In early April or May the Board of Education of each Independent School District (ISD) sends potential vendors a detailed description of upcoming contracts, a list of schools to be served, the contract period, the delivery times, and estimated quantities for four individual milk types: low-fat chocolate (LFC), low-fat white (LFW), whole white (WW), and whole chocolate (WC). WC is the most costly to produce, followed by WW, LFC and LFW. The invited vendors have to sign a Non-Collusive Affidavit, which states that the undersigned bidder did not and will not agree to participate or price with any other person. The major bid season ranges from early May to early August. On the day of letting, sealed bids are opened and all bidders are identified. The lowest bid becomes a winning bid. According to a list of criminal cases filed by the antitrust division involving the milk industry, 10 bid rigging cases for school milk were filed in Texas, and two cases are still pending. In 1992 and 1993 nine milk processors in the DFW area were charged with and pleaded guilty to rigging bids, and those which did business in this area paid more than $15million to settle the claims. But any major player in San Antonio market was not charged.

The major input in the production of milk is raw milk. The milk processors

[8] A comparison of the raw milk price in constant 1982 dollars in San Antonio and Tampa informs that the raw milk price in Tampa is about 14 percent higher. Inter-city cost of living indicators for Tampa is available only in the year of 1990. The composite cost of living index indicates that it is 1.85 percent higher in Tampa than in San Antonio. An index of transportation cost tells that the delivery cost is 1.28 percent higher in Tampa. The cost of living indicators of Bradenton and Lakeland, neighbor cities of Tampa, are available for the 1980-1990 sample period. If we use these cost of living indicators as an approximation of cost of living indicators for Tampa city, the composite cost of living index indicates that it is 3.8 percent higher in Tampa than in San Antonio. An index of transportation cost tells that the delivery cost is almost same between two cities. If all costs except raw milk are assumed to be 5 percent higher in Tampa than in San Antonio, the cost difference between San Antonio and Tampa is roughly 8.18 percent, still leaving the delivered cost lower in San Antonio.

remove all butterfat from the raw milk, pasteurize it, and mix it in varying proportions of fat content, along with flavor and other ingredients to produce four types of milk. The various types of milk products are then packaged and delivered. Raw milk is purchased from farmers or from dairy cooperatives at prices regulated by a series of federal milk marketing orders. There is 42 cents/cwt. location differential in raw milk cost between Dallas-Ft. Worth and San Antonio covered in this paper.[9] In terms of the half pint price, the raw milk price is 0.225 cents more expensive in the San Antonio market. Raw milk accounts for about 60-70 percent of the total cost. This helps to reduce the uncertainty of firms expectation on rival firms cost.[10] The combination of a relatively homogeneous cost structure for firms and the inelasticity of demand for school milk facilitates firms coordination on a focal point such as industry-profit-maximization strategy.

B. Data Description

Data are collected from a number of public sources. Principally data are from school bid documents, but also a variety of school directories, maps, atlases, and other sources. Data sets are constructed for seven major milk processors in the DFW market and six major milk processors in the San Antonio market. These firms are labeled with 1, 2, ..., 7 in the DFW market and 1, 2, ..., 6 in San Antonio market. The variables used in this study are as follows.

- INCUMBENCY, a dummy variable that equals one if a firm has won in the same district in the preceding period. This variable is a control for incumbency effects.
- BEGIN, a dummy variable that equals one if the bid season has not yet passed over 5 percent of bid season.[11] This controls for the reputation for friendly behaviors at the initial rounds of bid season.
- END, a dummy variable that equals one if the bid season has passed over 95 percent. This controls for the incentive to cheat at the end of the bid season.
- ENTRY, a dummy for Preston's entry in 1985. The dummy is used only where Preston bids in 1985.
- ONEBID, a dummy variable for only one bidder in a contract.
- NOBIDDER, the number of bidders in each contract.[12]

[9] 1 cwt. is equivalent to about 186 half pints. Dallas area and San Antonio area are Zone 1 and Zone 9, respectively, of Federal Milk Market Order 126.

[10] Milk delivery trucks typically supply retail stores, schools, and other facilities at the same time. The cost of a milk processor for a school milk contract will to some extent depend on what other stores or facilities are supplied in that area. It will also be affected by the firm's current capacity and processing cost.

[11] The definitions of Begin and End are rather arbitrary. I have also tried the first and last 10% of the season. But the estimated coefficients are almost not changed. These variables are put in a model to capture the change in bidding patterns at the first and last season.

[12] NOBIDDER is excluded from a model because the statistical tests are robust to the

• Type of Milk, low-fat chocolate (LFC), low-fat white (LFW), whole chocolate (WC) and whole white (WW). This factor is represented by binary variables in the model.

• FMO, Federal Milk Marketing Order Class 1 minimum raw milk price. These are the prices for Order 126, Zone 1 and Zone 9. This natural logarithm of FMO is used in the model.

• ESTQTY, the estimated total quantity to be supplied. The natural logarithm of the estimated total quantity is used in the models.

• QSTOP, the estimated quantity per milk truck stop in the district. This is calculated by dividing the total quantity expected to be supplied by the total number of stops necessary to supply this quantity. The total quantity expected to be supplied is provided in the bid specifications by the school district prior to the letting of the contract. The total number of stops is calculated by multiplying the total number of schools in the district by the total number of deliveries per week times the number of weeks in a school year. The natural logarithm of the quantity per stop is used in the models.

• BACK (backlog), defined as the percent of each vendor's half-pint capacity committed at the time of letting minus the percent of the bid season that passed at the time of letting. The BACK variable can range from -100% to 100%. A negative BACK implies that the dairy has more capacity than bid season remaining. Then it will bid more aggressively. A positive BACK means that the percent of the dairy's capacity that is committed exceeds the percentage of the districts that have opened bids to date. Then it will bid less aggressively. We would expect a dairy's bids to be positively correlated with BACK, all else equal.[13]

• BACKSQ, BACK*BACK to capture the nonlinear response of bids to the changes in backlog..

• ESC, the type of bid. This is an escalated price which will change if the raw cost of milk changes or a firm price which will not change over the course of the school year. Escalated prices are generally lower since the price can be adjusted throughout the school year. The escalation factor is a binary variable which is equal to one if the bid price is escalated and zero if it is firm.

Table 2 provides summary statistics for selected variables in both markets. It shows that the contracts are more frequently awarded in the DFW market and the average size of the contracts are 2.6 times bigger in the San Antonio market. It also illustrates that the changes in incumbency are more often observed in the San Antonio market. Average winning bids had been 2% to 8%

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inclusion and exclusion of NOBIDDER

[13] Here, BACK is defined on the basis of four types of the processed school milk, not raw milk. The above conjecture has a limit in the sense that dairies typically process more raw milk than they need to meet their requirements for grocery stores and other commercial customers.

[Table 2] Descriptive Statistics on Selected Variables

Year	# of Contracts		*Turnover Ratio		**Average Size of Contracts		***Average Wining Bids	
	DFW	SAN	DWF	SAN	DFW	SAN	DFW	SAN
80	43	4	0.0	–	980720	283727	.168	.155
81	50	8	7.5	0.0	944370	1527184	.173	.170
82	59	14	9.8	25.0	743046	1718710	.169	.168
83	64	14	8.9	28.5	674509	1506753	.164	.154
84	72	18	16.4	35.7	589494	1374774	.164	.162
85	102	17	11.8	11.7	492423	1463560	.162	.163
86	112	18	13.4	35.2	479060	1359436	.165	.161
87	125	19	23.0	44.4	445175	1376759	.166	.156
88	131	19	8.6	47.3	448459	1583832	.163	.128
89	131	18	12.9	55.5	448851	1642362	.166	.130
90	128	19	30.4	44.4	483377	1714362	.169	.143
91	110	14	12.2	10.0	518006	1425023	.157	.143
92	39	–	25.0	–	1139603	–	–	–
Mean			13.0	39.5	567462	1488693		

* Turnover ratio measures % changes in incumbency position.

** Average size of contracts is estimated quantities to be supplied, measured in half pint.

*** Average winning bids for Low Fat Chocolate in $/half pint.

lower in the San Antonio market until the year of 1986. Since 1987, the gap in average winning bids between two markets have significantly widened more than 20%.

Ⅳ. MODEL

The relevant cost for analyzing school milk bidding is marginal cost, which is equivalent to the incremental change in what dairies call dock cost due to a change in production of school milk, i.e., all of the related costs except distribution costs and GSA.[14] The framework of my empirical analysis is an equation with bids on the left hand side and with marginal cost-related factors and a set of strategic and structural variables on the right.[15] Three major cost-related variables implicitly control for firm specific effects, ISD specific effects, and time specific effects. The backlog variable (BACK) is firm specific. A firm with a large backlog of work may face large incremental costs for

[14] Most distribution costs such as truck depreciation, maintenance, fuel, and driver compensation, are normally allocated to commercial customers an a dedicated route. So, the only incremental distribution costs associated with school contracts sales are the commissions paid to drivers, which run about 5% of gross revenue.

[15] Lee(1998), Hewitt, C., McClave, J., and Sibley, D. (1993), and Porter, Robert and Zona, Douglas (1993) all follow same marginal cost approach in empirical studies of bidding behaviors.

additional job. Thus, a rise in BACK would tend to increase marginal cost. The estimated quantity per milk truck stop (QSTOP) is ISD specific and fairly stable over time. QSTOP controls for a certain fixed cost per half pint. The higher is QSTOP, the lower is this fixed cost per half pint. Thus, an increase in QSTOP would tend to lower marginal cost. Federal Milk Marketing Order Class 1 minimum milk price (FMO), monthly average data, is time specific, i.e., same across firms and districts. FMO inevitably raises marginal cost. Other than these marginal cost-related variables, ESC is a control for an Escalation Clause which allows prices to increase or decrease with raw milk prices. Escalated prices are generally lower since the price can be adjusted throughout the school year. As for the milk types, these can vary by school districts because different school districts sometimes ask for bids on different milk types. With respect to cost effects, WC is the most expensive, followed in order by WW, LFC and LFW. In addition to cost-related variables, a set of strategic and structural variables are put into the models: INCUMBENCY, BEGIN, END, ONEBID, and ENTRY.

I assume the bidding behavior satisfies the log-linear bidding rule as following:

$$log(b_{ijt}) = \beta X_{ijt} + \varepsilon_{ijt}, \tag{1}$$

where X_{ijt} is a vector of observable variables affecting firm is probability of winning for contract j at time t, and ε_{ijt} denotes private information, such as idiosyncratic cost effects for firm i on contract j at time t. The dependent variable is the logarithm of bids measured in half-pint price. X_{ijt} consists of marginal cost-related factors and a set of strategic and structural variables. In regard to the model specification, the analysis of residuals from this estimating equation shows that, based on a histogram, a boxplot, and a normal probability plot, the residuals appear to be bell-shaped and reasonably close to the normal distribution. I computed D-statistic, which rejected normality. Given the large number of samples, this is not unexpected. The approximate bell-shape of the histogram and the close correspondence with the normal quantities for most of the range of the residuals suggest that the empirical model is probably not seriously misspecified. OLS estimates are robust with regard to a minor deviation from normality given the large sample size. There is no multicollinearity problem among the explanatory variables. Sample selection issues are ignored because all eligible bidders submit bids.

V. TEST RESULTS

A. The Existence of Different Equilibria Between Markets

Table 3 shows that a turnover, a change in incumbency in DFW market, occurs on average 79 percent of the bid seasons over 1980-1992 and a turnover

[Table 3] The Occurrence of Change in Incumbency over Bid Season (unit: %).

Year	The bid season the first turnover occurs		Average bid season a turnover occurs	
	DFW	SAN	DFW	SAN
80	38.24	38.16	82.20	44.00
81	48.92	38.73	79.80	60.62
82	35.29	7.33	64.55	81.02
83	59.46	92.46	79.91	94.94
84	45.10	6.58	61.58	53.50
85	55.84	38.61	82.45	38.61
86	45.63	30.21	78.52	70.57
87	37.65	25.84	76.22	64.77
88	31.51	21.33	70.65	60.13
89	48.74	22.99	74.10	72.19
90	44.75	49.72	89.37	68.90
91	32.68	61.65	78.91	65.72
92	33.54	–	68.19	–
Mean	42.97	31.44	78.83	68.44

in San Antonio market occurs on average 68.44 percent of the bid seasons over 1980-1991.[16]

Table 3 implies that the turnover distribution on bid season have too much weight on the end tail of bid season in both markets. The first turnover in DFW market occurs on average after a 42 percent lapse of bid season and the first turnover in San Antonio market occurs on average after a 31.44 percent lapse of bid season, both well into bid season.[17] If this game is an infinitely repeated game, the intensive defection at the end of bid season should be punished at the beginning of bid season. These two pieces of statistical evidence on firms bidding behavior suggest that firms act as if the history of intensive defection at the end of bid season will not be transferred to the new bid season. In other words, the firms decision horizon turns out to be short at the end of bid season.

The estimated coefficient on END is negative and statistically significant, i.e., a 3.25 percent decrease in average total bids and a 3.4 percent drop in average winning bids at the end of bid season in DFW market(Table 4).

Firms engage in statistically significant price shading at the end of season. Systematic price shading at the end of bid season is also observed in San Antonio market, i.e., 3.51% down in average total bids and 3.74% down in

[16] Here, the bid season is measured as the percent of the bid season that passed at the date of letting

[17] The fact that the average first turnover occurs 42% into the season resembles what is observed in finitely prisoner's dilemma experiments, where players cooperate an average of four out of ten periods. See for instance Selten and Stoecker (1986).

[Table 4] DFW Major Milk Processors

Dependent Variable: logarithm of bid price (bid price in $/half pint)

	Total Bids (Winning Bids plus Losing Bids)			Winning Bids		
Explanatory Variables	Parameter Estimate	T-Statistic	Pr>|T|	Parameter Estimate	T-Statistic	Pr>|T|
INTERCEP	−1.037	−20.87	0.0001	−.7962	−10.19	0.0001
INCUMBENCY	−0.046	−23.36	0.0001	0.015	4.27	0.0001
BEGIN	0.035	6.86	0.0001	0.020	1.79	0.0735
END	−0.032	−12.52	0.0001	−.034	−9.58	0.0001
ENTRY	−0.011	−3.54	0.0004	0.004	0.85	0.3934
ONEBID	0.020	6.81	0.0001	0.024	7.03	0.0001
LFC	−0.003	−1.36	0.1748	−.005	−1.42	0.1544
LFW	−0.047	−20.18	0.0001	−.049	−13.22	0.0001
WC	0.052	20.18	0.0001	0.053	13.35	0.0001
FMO	0.251	14.55	0.0001	0.318	11.86	0.0001
QSTOP	−0.003	−2.50	0.0123	−.0127	−5.48	0.0001
BACK	0.0006	11.40	0.0001	0.0002	2.83	0.0047
BACKSQ	0.000003	2.30	0.0216	−.000007	−2.61	0.0090
ESC	−0.0137	−6.78	0.0001	−.0068	−2.06	0.0394
Obs		6029			2387	
R^2		0.30427			0.30572	
F Value		202.36			80.38	
PR>F		0.0001			0.00001	

average winning bids(Table 5).

The estimated coefficients on Begin, controlling for friendly behavior at the beginning of bid season, are statistically significant in both markets; 3.5% up in average total bids and 2.0% up in average winning bids in DFW market, and 11.34% up in average total bids and 9.41% up in average winning bids in San Antonio market(Table 4 & 5). As the theory predicts, no defection in early stages of game and systematic price chiseling at the last rounds of the game are equilibrium outcomes in the finitely repeated game. The equilibrium strategy to raise milk prices in excess of competitive level in DFW market is complementary bidding scheme. After controlling for cost factors, major dairies in DFW school milk market shade their prices on average 4.68% lower in the contracts won in the previous year than in the contracts not won in the preceding year, as the estimated coefficient on INCUMBENCY variable indicates. The estimated coefficient on INCUMBENCY variable in winning bids sample tells that they recoup their incumbency premium. They appropriate 1.57% higher returns in incumbent districts than in nonincumbent districts. If a firm is a solo bidder as well as an incumbent supplier, its premium will be about 4%.

[Table 5] San Antonio Major Milk Processors

Dependent Variable: logarithm of bid price (bid price in $/half pint)

	Total Bids (Winning Bids plus Losing Bids)			Winning Bids		
Explanatory Variable	Parameter Estimate	T-Statistic	Pr>|T|	Parameter Estimate	T-Statistic	Pr>|T|
INTERCEPT	−.768	−3.64	0.0003	0.437	1.05	0.2928
INCUMBENCY	−047	−5.17	0.0001	0.041	3.02	0.0027
BEGIN	0.113	7.28	0.0001	0.094	3.81	0.0002
END	−.035	−3.86	0.0001	−.037	−2.26	0.0243
LFC	−.024	−2.71	0.0067	−.041	−2.54	0.0117
LFW	−.068	−7.64	0.0001	−.080	−5.01	0.0001
WC	0.048	4.06	0.0001	0.049	2.36	0.0191
FMO	0.256	3.39	0.0007	0.606	4.09	0.0001
QSTOP	−.0219	−3.84	0.0001	−.046	−4.32	0.0001
BACK	−.000003	−0.03	0.9796	−.000005	−0.01	0.9901
BACKSQ	0.0000008	0.40	0.6862	0.0000001	0.21	0.8328
ESC	−.0707	−9.02	0.0001	−.0485	−3.05	0.0025
Obs		1117			315	
R^2		0.28227			0.39331	
F Value		39.51			17.86	
PR>F		0.0001			0.0001	

Table 5 indicates that the complementary bidding strategy to allocate school milk accounts is also exercised and a statistically significant incumbency premium is recouped in San Antonio market. After controlling for the cost factors, six main suppliers shave their prices below average bids by 4.7% in the incumbent districts and the average winning bids in the ISDs where firms won in the same ISDs in the previous year is 4.1% higher than average winning bids in the ISDs where firms have not won in the previous year in San Antonio market.[18] Milk processors have enjoyed statistically significant incumbency premia in both markets even though average winning bids are lower in San Antonio market.

Tit-for-tat has played a crucial role in sustaining the cooperative equilibrium in the non-cooperative environment in both markets.[19] Firms keep incumbency

[18] It is not surprising that the incumbency premium is relatively higher in the San Antonio market, considering that average winning bids is significantly higher in the DFW market. While the 1.57% incumbency premium in the DFW market seems small and insignificant, it represents at least 0.5 cents on top of an already inflated price, on average, nearly 3 cents higher than a competitive price.

[19] Theory tells that if the equilibrium strategies were non-cooperative, the perturbed player may play tit-for-tat thus pretending to be the automaton and thereby convincing his opponent that this is in fact the case. Then, tit-for-tat induces nearly the cooperative outcome itself as the best

rule fairly well because punishments on deviations from the incumbency rule are strictly enforced.[20] About nine out of ten turnovers are punished and not ignored in DFW market.[21] About 6 out of ten turnovers are punished in San Antonio market.

The winning bid differentials between two markets are attributed to the difference in average turnover ratios, the average bid season in which a defection occurs (Table 2 & Table 3). Clearly the average turnover ratio is lower in the DFW market. The incumbency rule is more strictly observed in the DFW market. A defection is more likely to occur in the early bid season in the San Antonio market. Another reason that different equilibria are supported can be found in the differences in the number of repeated contracts in a bid season and the size of the contracts (Table 2). Lumpiness and infrequency of orders are more prominent in the San Antonio market. The average size of contracts in the San Antonio market is roughly 2.6 times larger than average size of contracts in DFW market. The frequency of contracts awarded in a bid season is in more contrast between the two markets. The effectiveness of oligopolistic coordination depends upon the size and frequency over time of buyers orders. Profitable coordination is the most likely when orders are small, frequent, and regular. It

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reply. Another possible interpretation of higher equilibrium winning bids traces back to a game theoretical model Ortega-Reichert (1967) has developed of tacit collusion for first-bid auctions in an extension of conscious parallelism. The idea is that by charging a high price in the current auction, each firm tries to signal to other firms that it is less cost effective than it really is, and thereby to indicate that it will not price aggressively in the next auction. It thus induces its rivals to price less aggressively in the future. This strategy may be rational behavior in the sense that the firm sacrifices short-run profits by raising its price in order to build a reputation for charging high prices in a repeated game with asymmetric information about marginal cost. In a repeated auction, each firm may try to convince its rivals that it is inefficient and, therefore, likely to bid high in the future as a automaton cultivates a rival player's doubt in Kreps et. al (1982). If the cultivation succeed in both cases, the equilibrium outcomes are beneficial to competing firms.

[20] The tit-for-tat strategy seems to be 'robust' in a sense that it does relatively well against a variety of other rules. For instance, Axelord (1984) points out that in the repeated PD game, tit-for-tat tends to be a robust rule because each player cooperates, is provoked into retaliation by the defection of the opponent, and yet is forgiving after he takes his own retaliation. The tit-for-tat strategy of beginning with cooperation and then matching one's rival's previous move has extremely attractive survival properties in environments consisting of a variety of alternative rules. In contrast, the 'always fink' rule of backward induction forbids gains from cooperation with cooperative types, while the 'always fink' after deviation rule of trigger strategy equilibrium is not forgiving enough in case of mistakes. Firms are supposed to apply the Bertland competition as maximal punishment, forever after the deviation. Then, the choice of an efficient equilibrium raises the issue of renegotiation. The firms, who expect no profits from the starting period of Bertland competition after deviation from a collusive agreement, have an incentive to renegotiate to avoid the punishment phase and reach an efficient equilibrium anew.

[21] Taking an example in DFW market, Milk Processor 1 took away Grandview ISD (74,000) in Johnson county from Milk Processor 2 by defection on August 1, 1988. In return, on August 3, 1988, Milk Processor 2 undercut Milk Processor 1's bid in Como-Pickton ISD (51,768) in Hopkins county, where Milk Processor 1 was an original incumbent.

is least likely when requests for price quotations in larger orders are received infrequently. The larger the stake, the greater the temptation to defect from the collusive agreement, because the effectiveness discount rate is larger.[22] As McAfee and McMillan (1992) suggest, in the case of contract bidding, it is better to offer a project as a single large contract than to break it up into smaller contracts.

B. The Dynamic Transition of an Equilibrium within a Market

A test of different equilibria within a market is carried out, based on the statistical evidence that sharp decline in average winning bids since 1987 in the San Antonio market has been consistent. This transition is permanent, not temporary.[23] The dynamic transition of a non-cooperative equilibrium within a market is observed without any changes in strategy sets and without any external shocks like new entry, or significant cost or demand disturbances. We statistically reject the hypothesis of no structural change between two subperiods(1980-1986 vs. 1987-1991), F (11, 1649) = 60.35.

[Table 6] San Antonio Major Milk Processors (Sample Period: 87-91)

Dependent Variable: logarithm of bid price (bid price in $/half pint)

	Total Bids(Winning Bids plus Losing Bids)			Winning Bids		
Explanatory Variables	Parameter Estimate	T-Statistic	Pr>|T|	Parameter Estimate	T-Statistic	Pr>|T|
INTERCEPT	−.522590	−2.37	0.0181	0.565387	2.14	0.0341
INCUMBENCY	−.062183	−5.80	0.0001	0.045794	4.57	0.0001
BEGIN	0.158142	9.45	0.0001	0.069431	3.10	0.0023
END	−.062756	−4.77	0.0001	−.043934	−2.83	0.0052
LFC	−.038199	−3.60	0.0003	−.053743	−4.30	0.0001
LFW	−.075198	−7.23	0.0001	−.085960	−7.09	0.0001
WC	0.055883	3.76	0.0002	0.058026	3.55	0.0005
FMO	0.233499	3.36	0.0008	0.468037	5.56	0.0001
QSTOP	0.000222	−5.59	0.0001	−.080416	−8.64	0.0001
BACK	−.000006	1.62	0.1057	0.000136	0.47	0.6356
BACKSQ		−2.14	0.0327	−.000010	−2.35	0.0199
Obs		701			182	
R^2		0.33437			0.67771	
F Value		34.66			35.96	
PR>F		0.0001			0.0001	

[22] Lumpiness of orders contributed to the poor pre-1960s pricing discipline of the electrical equipment industry. See Sultan (1974) for detailed story.

[23] See Table 2.

We accept two hypotheses at a significant level that milk processors have kept the complementary bidding strategy and that the incumbency premium has been still going on after precipitation of average winning bids since 1987, on average 6.21% price shading and 4.58% incumbency premium in the contracts in which they won in the previous year (Table 6). In conclusion, a complementary bidding strategy can be exercised at the different levels of winning bids and incumbency premia can be obtained at the different levels of supra-competitive profits.

Ⅵ. CONCLUDING REMARKS

The Texas school milk bid data containing a variety of information on cost factors and strategic behaviors is a natural setting for testing the hypotheses related with strategic interactions between competing firms in an oligopolistic industry. Fairly strict tit-for-tat strategies actually keep firms from defecting and maintain stability in market share dispersion among firms over time, and thus raise prices far in excess of the competitive level in both markets. Milk processors in DFW and San Antonio market have engaged in a complementary bidding strategy to allocate consumers and to have recouped incumbency premia. The existence of multiple equilibria, another aspect of Folk Theorem is empirically tested, exploiting the almost same game environment between DFW and San Antonio market. The same strategy profiles (complementary bidding strategy, tit-for-tat strategy, systematic price shading at the end of bid season, and friendly behavior at initial rounds of game in both markets) support different equilibria in the forms of different levels of winning bids and different levels of non-cooperative tacit collusion. Statistical analysis reveals that even though there was substantial cost advantage in the San Antonio market, school milk prices were higher in the San Antonio market than in the repeatedly bid-rigged Florida market in the 1980s. The milk processors in Florida market were engaged in overt collusion by rotating bidding scheme, where a winner is chosen in advance.[24] This fact implies that antitrust agency needs to reallocate its monitoring resources more to the detection of noncooperative tacit collusion, where some pieces of circumstantial evidence may be sufficiently convincing to enable dispensing with evidence of actual communication between rival firms.

[24] The repeated bid-rigging in Florida market, even though repeatedly detected and punished by antitrust agency, implies that the expected benefit out of bid-rigging is bigger than the expected cost out of detection and punishment.

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