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Experimental Evidences from Prisoner's Dilemma and One Shot Games in Duopoly Markets in Bangladesh

L. C. Das*, J. Ferdous, S. Taher & W. Z. Loskor
Lecturer, Department of Mathematics, University of Chittagong, Bangladesh
Lecturer, Department of Mathematics, Premier University, Bangladesh
Assistant Professor & Associate Professor, Department of Science and Humanities, Bangladesh Army International University of Science & Technology
Corresponding Author: L. C. Das

Abstract: *In this paper, game theory is applied to the selling decision to establish that shopkeepers are locked in "prisoner's dilemma" and one shot game over the decision. Individual rationality has pushed both shopkeepers in a duopoly market to adopt a dominating strategy, leading to several full-fledged and limited wars. However, collective rationality brings about peace as a Pareto-optimal solution under game theory. An attempt has also been made to show how two shopkeepers can mitigate their dilemma by using the strategies meant for mitigating the prisoner's dilemma in game theory.*

Keywords: *Duopoly, prisoner's dilemma, one shot game, revenue, game value.*

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I. Introduction

Self-serving, rational agents sometimes cooperate to their mutual benefit. However, when and why cooperation emerges is surprisingly hard to pin down. To address this question, scientists from diverse disciplines have used the Prisoner's Dilemma, a simple two-player game, as a model problem. A human cannot live alone without the help of others and has to make a relationship with people based on mutual cooperation. A human has contradictory aspects: cooperation and selfishness. It is a challenge to explain this contradiction of human cooperation, and many pioneers found some conditions that cooperation occurs [1-3]. Recently, evolutionary game theory has been used to explain how cooperation occurs [4, 5]. The evolutionary game theory has two major concepts. The first one is game. Among many kinds of games, it has been studied a lot and found that Prisoner's Dilemma (PD) game well expresses human selfishness [6-8]. The other major concept is the imitation process. In this paper, we also use the PD game. For nearly a century now game theory has influenced the way we think about the world. It has entered into the study almost every type of human interaction, including economics, political science, war games, and evolutionary biology. This is because, at its core, game theory seeks to explain how rational players should behave to best serve their own interests.

II. Materials and methodology

The tools being used to analyze the behavior of customers in rural shops (10 shops) mostly from game theory, a branch of applied mathematical economics which give formal mathematical models for the behavior of individuals in situations of conflicting interests [9]. For selecting the respondents, a convenience sampling technique was used in this study. In order to collect data, 10 shopkeepers from different villages were selected. The authors spent forty separate days to collect data from the selected shopkeepers. The models of game theory assume intelligent and rational decision makers. An intelligent decision maker is one that understands everything about the structure of the interaction, including the available information, assumptions, but also the fact that other decision makers are intelligent and rational. Rational decision makers always make decisions that are in their own best interest, which typically means maximizing an expected utility function. Game theory started out as a branch of economics, but its potential to model and analyze human behavior in a variety of situations was soon understood and it was applied in different rural shops [10]. Open questions are employed to open up for a conversation with the respondents (shopkeepers), to reveal their unique experiences of prisoner's dilemma and one shot game strategies taken by them.

III. Related concepts

Oligopoly Market Structures:

Markets differ from each other based on three important criteria:
(i) The number of firms in a market;
(ii) The ease of entry into and exit from the market; and
(iii) The ability of firms to differentiate their products and hence exercise some control over price.

An oligopoly is a market with few firms selling products that may be differentiated. An oligopoly is a price setter (like a monopoly) and ability of new firms to enter is usually limited, though not completely barred. The prefix oligo- means few. An example of an oligopolistic market is the automobile market in the U.S. or the telecom industry in Bangladesh. To understand how firms operate in an oligopolistic market, we have to use some knowledge about a branch of economics called strategy and game theory.

● Unlike a monopoly or a competitive firm, an oligopolistic firm considers how it's actions affect it's rivals and how it's rivals' actions affect it; each firm forms a strategy. A strategy is a "battle plan" or a plan of action that each firm will use to compete against the other firm in this oligopolistic market. In the models, strategies usually involve setting prices and/or quantities.

●We think of oligopolies as players competing with each other in a game {a game is a competition or contest between players where strategic behavior plays a key role. Game theory is a set of tools that economists, political scientists and military analysts use to analyze these game scenarios [11].

●A set of strategies is a Nash equilibrium if, holding the strategies of all other players (or firms) constant, no player (or firm) can obtain a higher pay-off (or profit) by choosing a different strategy. In the Nash equilibrium, no firm wants to change its strategy because each firm is using its best response {the strategy that maximizes its pay offs', given its beliefs about other players' strategies} [12].

Duopoly:

A true **duopoly** is a specific type of oligopoly where only two producers exist in one market. In reality, this definition is generally used where only two firms have dominant control over a market. Duopoly analysis by economists dates back to the 19th century. Some of the central concepts of duopoly analysis have to do with strategic behavior, and the analysis of strategic behavior is the heart of the 20th century discipline called game theory. So game theory builds on duopoly theory.

Total Revenue:

Total revenue is the total money received from the sale of any given quantity of output. It can be calculated as the selling price of the firm's product times the quantity sold, i.e. total revenue = price × quantity, TR (Q) = P (Q) × Q, where Q is the quantity of output sold, and $P(Q)$ is the inverse demand function (the demand function solved out for price in terms of quantity demanded).[13]

Prisoner's dilemma:

Much attention has been paid in particular to cooperative play in the prisoner's dilemma (PD) game. In Game PD below, each player has a dominant strategy: he should fink regardless of his expectation regarding his rival's play and the outcome of (fink, fink) is therefore predicted. The important feature of this game is that this outcome is not Pareto-optimal. Indeed, the outcome in which both players cooperate Pareto-dominates (fink, fink) and maximize joint payoffs.

Player II

Player I

	Fink	Co-operate
Fink	b, b	c, d
Co-operate	d, c	a, a

Game PD: c>a>b>d

Experimental evidence on games of this form repeatedly reveals that some players cooperate [14]. While the design of these experiments has varied widely in terms of the frequency of play and the number of times a player faces the same opponent, the observed cooperative play is quite robust to these changes.

One shot game:

Two main types of theories have been offered to explain why players cooperate in PD games. The first applies only to agents playing the game repeatedly and involves history-dependent strategies. These theories, associated with Kreps *et al.*, maintain the assumption of self-interested players and rely on the repeated nature of the game to create incentives for cooperation.

In these models, the key assumption is that players hold a small belief that their opponent is a cooperative player and this induces the self-interested players to cooperate in a finitely repeated PD game. The second type of theory postulates that at least some agents are not strictly self-interested and benefit from cooperation in a manner not reflected in the payoff matrix provided in PD experiments. We discuss the implication of these models for observed play of one-shot only.

i. Reputation. The Kreps *et al.* model assumes that, while players believe that a fraction of their opponents are altruists, all players are in fact egoists. While these ''irrational beliefs'' have considerable power in generating cooperative play in finitely repeated games, it is equally clear that in a sequence of one-shot games, the theory of Kreps *et al.* predicts that cooperation rates will be zero.

ii. Altruism. In models with altruism, in contrast, there are assumed to be a subset of players for who cooperate is not a dominated strategy. To study this, we restrict attention to a ''warm glow'' model in which a player receives an additional payoff by cooperating in the PD game. Consider the following payoff matrix where the entries correspond to the payoffs of Game PD except that the row player is assumed to be an altruist.

Egoist

Altruist

	Fink	Co-operate
Fink	b, b	c, d
Co-operate	δ + d, c	δ + a, a

This is a ''warm glow'' model in that the payoffs of the row player in the event cooperate (C) is chosen are augmented by $\delta \geq 0$. In general, we will assume that δ is distributed across the population according to a cumulative distribution function $G(\delta)$. When $\delta = 0$ this game is the same as Game PD.

Case i: We term players with δ less than min (b - d, c - a) *egoists* since fink (F) is a dominant strategy for them.

Case ii: If δ exceeds both b-d and c-a, then cooperate becomes a dominant strategy for the row player. We term players with payoffs satisfying these restrictions dominant strategy altruists.

Case iii: If δ exceeds c - a, but is less than b - d, then cooperate is no longer a dominant strategy so that cooperative play could be rationalized only by a belief that a rival is cooperating with a sufficiently high probability. Players with these preferences are best response altruists. As long as there are enough players with $\delta > c - a$, this framework rationalizes observed cooperative play in one-shot games.

Clearly, if there are dominant strategies altruists, those players will cooperate in all periods of play. If there are only best response altruists, equilibrium always exists in which altruists and egoists fink [15]. However, if the proportion of altruists in the cohort is large enough ($G(c - a)$ is sufficiently small), then there will also exist an equilibrium in which the altruists cooperate and the egoists fink. Finally, when this equilibrium exists, there will also exist a third equilibrium in which the egoists fink and the altruists randomize between fink and cooperate. Thus, a model with best response altruists can have multiple Nash equilibrium which can be Pareto-ranked. Note that absent learning, there is no reason for the distribution of play to change over time in a sequence of one-shot plays of this game.

IV. Experimental observation

Experiment 1:

Observation 1.1: item (Tomato)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 12	Tk 12
Customer (per day)	10	10
Revenue	Tk 120	Tk 120
New price (per kilogram)	Tk 9	Tk 9
New customer (per day)	15	15
Revenue	Tk 135	Tk 135
Gain	Tk 15	Tk 15

Observation 1.2: item (Tomato)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 12	Tk 12
Customer (per day)	10	10
Revenue	Tk 120	Tk 120
New price (per kilogram)	Tk 11	Tk 14
New customer (per day)	14	9
Revenue	Tk 154	Tk 126
Gain	Tk 34	Tk 6

Observation 1.3: item (Tomato)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 12	Tk 12
Customer (per day)	10	10
Revenue	Tk 120	Tk 120
New price (per kilogram)	Tk 14	Tk 11
New customer (per day)	9	14
Revenue	Tk 126	Tk 154
Gain	Tk 6	Tk 34

Observation 1.4: item (Tomato)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 12	Tk 12
Customer (per day)	10	10
Revenue	Tk 120	Tk 120
New price (per kilogram)	Tk 19	Tk 19
New customer (per day)	8	8
Revenue	Tk 152	Tk 152
Gain	Tk 32	Tk 32

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	15,15	34,6
Increase in price	6,34	32,32

Here a=32, b=15, c=34, d=6 Game PD: c>a>b>d

One shot game:

Case 1: δ< min (b-d, c-a), or, δ< min (15-6, 34-32), or δ< min (9, 2), or, δ< 2. let : δ=1.

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	15,15	34,6
Increase in price	7,34	33,32

Case ii: δ>b-d and δ>c-a or, δ>15-6 and δ>34-32, or , δ>9 and δ>2 let : δ=10

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	15,15	34,6
Increase in price	16,34	42,32

Case iii: δ<b-d, but δ>c-a, or δ<15-6, but δ>34-32, or δ<9, but δ>2 let : δ=5

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	15,15	34,6
Increase in price	11,34	37,32

Experiment 2:

Observation 2.1: item (Egg Chop)

	1st shopkeeper	2nd shopkeeper
Initial price(per unit)	Tk 10	Tk 10
Customer(per day)	20	20
Revenue	Tk 200	Tk 200
New price(per unit)	Tk 8	Tk 8
New customer(per day)	28	28
Revenue	Tk 224	Tk 224
Gain	Tk 24	Tk 24

Observation 2.2: item (Egg Chop)

	1st shopkeeper	2nd shopkeeper
Initial price(per unit)	Tk 10	Tk 10
Customer(per day)	20	20
Revenue	Tk 200	Tk 200
New price(per unit)	Tk 9	Tk 13
New customer(per day)	26	16
Revenue	Tk 234	Tk 208
Gain	Tk 34	Tk 8

Observation 2.3: item (Egg Chop)

	1st shopkeeper	2nd shopkeeper
Initial price(per unit)	Tk 10	Tk 10
Customer(per day)	20	20
Revenue	Tk 200	Tk 200
New price(per unit)	Tk 13	Tk 9
New customer(per day)	16	26
Revenue	Tk 208	Tk 234
Gain	Tk 8	Tk 34

Observation 2.4: item (Egg Chop)

	1st shopkeeper	2nd shopkeeper
Initial price(per unit)	Tk 10	Tk 10
Customer(per day)	20	20
Revenue	Tk 200	Tk 200
New price(per unit)	Tk 15	Tk 15
New customer(per day)	15	15
Revenue	Tk 225	Tk 225
Gain	Tk 25	Tk 25

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	24,24	34,8
Increase in price	8,34	25,25

Here, a=25, b=24, c=34, d=8. Game PD: c>a>b>d

One shot game:

Case i: δ<min (b-d, c-a), or, δ<min (24-8, 34-25), or δ<min (16, 9), or, δ< 9. let : δ=8

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	24,24	34,8
Increase in price	16,34	33,25

Case ii: δ>b-d and δ>c-a or, δ>24-8 and δ>34-25, or, δ>16 and δ>9. let: δ=17

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	24,24	34,8
Increase in price	25,34	42,25

Case iii: δ<b-d, but δ>c-a or δ<24-8 but δ>34-25 , or δ<16, but δ>9 let : δ=10

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	24,24	34,6
Increase in price	18,34	35,25

Experiment 3:

Observation 3.1: item (Potato)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 18	Tk 18
Customer(per day)	30	30
Revenue	Tk 540	Tk 540
New price(per kilogram)	Tk 15	Tk 15
New customer(per day)	38	38
Revenue	Tk 570	Tk 570
Gain	Tk 30	Tk 30

Observation 3.2: item (Potato)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 18	Tk 18
Customer(per day)	30	30
Revenue	Tk 540	Tk 540
New price(per kilogram)	Tk 17	Tk 19
New customer(per day)	36	29
Revenue	Tk 612	Tk 551
Gain	Tk 72	Tk 11

Observation 3.3: item (Potato)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 18	Tk 18
Customer(per day)	30	30
Revenue	Tk 540	Tk 540
New price(per kilogram)	Tk 19	Tk 17
New customer(per day)	29	36
Revenue	Tk 551	Tk 612
Gain	Tk 11	Tk 72

Observation 3.4: item (Potato)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 18	Tk 18
Customer(per day)	30	30
Revenue	Tk 540	Tk 540
New price(per kilogram)	Tk 24	Tk 24
New customer(per day)	25	25
Revenue	Tk 600	Tk 600
Gain	Tk 60	Tk 60

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	30,30	72,11
Increase in price	11,72	60,60

Here a=60, b=30, c=72, d=11 Game PD: c>a>b>d

One shot game:
Case i: $\delta<$ min (b-d, c-a), or, $\delta<$min (30-11, 72-60), or $\delta<$min(19, 12), or, $\delta<$ 12. Let: δ=10

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	30,30	72,11
Increase in price	21,72	70,60

Case ii: $\delta>$b-d, and $\delta>$c-a, or $\delta>$30-11 and $\delta>$72-60, or, $\delta>$19 and $\delta>$12. let: δ=20

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	30,30	72,11
Increase in price	31,72	80,60

Case iii: $\delta<$b-d, but $\delta>$c-a or $\delta<$30-11, but $\delta>$72-60, or $\delta<$19, but $\delta>$12 Let : δ=15

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	30,30	72,11
Increase in price	26,72	75,60

Experiment 4:

Observation 4.1: item (Brinjal)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 20	Tk 20
Customer(per day)	25	25
Revenue	Tk 500	Tk 500
New price(per kilogram)	Tk 18	Tk 18
New customer(per day)	30	30
Revenue	Tk 540	Tk 540
Gain	Tk 40	Tk 40

Observation 4.2: item (Brinjal)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 20	Tk 20
Customer(per day)	25	25
Revenue	Tk 500	Tk 500
New price(per kilogram)	Tk 19	Tk 23
New customer(per day)	29	23
Revenue	Tk 551	Tk 529
Gain	Tk 51	Tk 29

Observation 4.3: item (Brinjal)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 20	Tk 20
Customer(per day)	25	25
Revenue	Tk 500	Tk 500
New price(per kilogram)	Tk 23	Tk 19
New customer(per day)	23	29
Revenue	Tk 529	Tk 551
Gain	Tk 29	Tk 51

Observation 4.4: item (Brinjal)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 20	Tk 20
Customer(per day)	25	25
Revenue	Tk 500	Tk 500
New price(per kilogram)	Tk 26	Tk 26
New customer(per day)	21	21
Revenue	Tk 546	Tk 546
Gain	Tk 46	Tk 46

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	40,40	51,29
Increase in price	29,51	46,46

Here a=46, b=40, c=51, d=29 Game PD: c>a>b>d

One shot game:

Case i: $\delta<$ min (b-d, c-a), or, $\delta<$ min (40-29, 51-46), or $\delta<$ min (11, 5), or, $\delta< 5$. let : $\delta=4$

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	40,40	51,29
Increase in price	33,29	50,46

Case ii: $\delta>$b-d and $\delta>$c-a or, $\delta>$40-29 and $\delta>$51-46, or, $\delta>11$ and $\delta>5$. let : $\delta=12$

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	40,40	51,29
Increase in price	41,29	58,46

Case iii: $\delta<$b-d, but $\delta>$c-a or $\delta<$40-29, but $\delta>$51-46, or $\delta<11$, but $\delta>5$ let: $\delta=7$

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	40,40	51,29
Increase in price	36,29	53,46

Experiment 5:

Observation 5.1: item (Rice)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 40	Tk 40
Customer(per day)	15	15
Revenue	Tk 600	Tk 600
New price(per kilogram)	Tk 34	Tk 34
New customer(per day)	18	18
Revenue	Tk 612	Tk 612
Gain	Tk 12	Tk 12

Observation 5.2: item (Rice)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 40	Tk 40
Customer(per day)	15	15
Revenue	Tk 600	Tk 600
New price(per kilogram)	Tk 37	Tk 43
New customer(per day)	17	14
Revenue	Tk 629	Tk 602
Gain	Tk 29	Tk 2

Observation 5.3: item (Rice)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 40	Tk 40
Customer(per day)	15	15
Revenue	Tk 600	Tk 600
New price(per kilogram)	Tk 43	Tk 37
New customer(per day)	14	17
Revenue	Tk 602	Tk 629
Gain	Tk 2	Tk 29

Observation 5.4: item (Rice)

	1st shopkeeper	2nd shopkeeper
Initial price(per kilogram)	Tk 40	Tk 40
Customer(per day)	15	15
Revenue	Tk 600	Tk 600
New price(per kilogram)	Tk 48	Tk 48
New customer(per day)	13	13
Revenue	Tk 624	Tk 624
Gain	Tk 24	Tk 24

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	12,12	29,2
Increase in price	2,29	24,24

Here a=24, b=12, c=29, d=2 Game PD: c>a>b>d

One shot game:

Case i: δ< min (b-d, c-a), or, δ< min (12-2, 29-24), or δ< min (10, 5), or, δ< 5. Let: δ=3

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	12,12	29, 2
Increase in price	5, 29	27, 24

Case ii: δ>b-d and δ>c-a or, δ>12-2 and δ>29-24, or, δ>10 and δ>5. let: δ=12

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	12,12	29,2
Increase in price	14,29	36,24

Case iii: $\delta<b-d$, but $\delta>c-a$ or $\delta<12-2$, but $\delta>29-24$, or $\delta<10$, but $\delta>5$ let : $\delta=7$

Pay off matrix:

2nd shopkeeper

1st shopkeeper

	Decrease in price	Increase in price
Decrease in price	12,12	29,2
Increase in price	9, 29	31,24

V. Results

We have shown that if two shopkeepers' individually change product price, one shopkeeper will gain maximum profit and another will gain minimum profit. On the other hand, if both of them mutually change the product price after discussing with one another, they will gain equal profit.

VI. Conclusions

We have observed the effects of prisoner's dilemma game in duopoly market. At PD game, each player has a dominant strategy. In this game, the outcomes are not pareto-optimal. It is also mentionable that one shot game is used to determine minimum difference of prices. Experimental evidence on games of this form reveals that some players cooperate repeatedly. Cooperative play is observed in both repeated and one-shot environments.

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Appendices:

Observations	Address
Observation 1: ShopKeeper 1: Nishit Biswas Shopkeeper 2: Srikanta Boidya	Burigoalini, Shyamnagor, Satkhira
Observation 2: ShopKeeper 1: Santush Kumar Mazi Shopkeeper 2: Bijoy Chandra Mazi	Durgahpur, Assasuni, Satkhira
Observation 3:	Sanulia, Tala, Satkhira

Shopkeeper 1: Md. Kamal Hossain Shopkeeper 2: Md. Jahangir Alam	
Observation 4: ShopKeeper 1: Sudhanshu Mistri Shopkeeper 2: Abijit Mridha	Prembag, Abhoynagar, Jessore
Observation 5: ShopKeeper 1: Yusuf Mia Shopkeeper 2: Abul Hossain	Hakimpur, Chowgacha, Jessore

L. C. Das. "Experimental Evidences from Prisoner's Dilemma and One Shot Games in Duopoly Markets in Bangladesh." IOSR Journal of Mathematics (IOSR-JM) 15.2 (2019): 29-39.