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Empirical evidences of two person zero sum game in duopoly markets in Bangladesh

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Abstract: *This paper surveys the literature in which zero sum game has been proved in empirical duopoly market in rural area. In this survey of duopoly models, techniques of game theory are adapted to find market equilibrium and understand deciding forces for firms. We look at situations with increasing complexity, to develop a better understanding of the usefulness of the game theory in market analysis. Initially, we explore the basics of game theory. Then, following an introduction of basic microeconomics, we explore simple static games of competitive interaction. Finally, we add complexity to these models to explore the game value. We concentrate on the research on structure and performance since game theory made its most profound inroads in this field and in small business in general, and while it now spreads to all other fields in economics - empirical applications are coming up with an increasing rate. We discuss the goals, results and problems involved in the existing literature and propose topics and methods which look promising. We expect empirical work based on game theoretical models to become a growth area in the field of economics following the progress made in theory over the past decades.*

Keywords - *Duopoly, zero sum game, pay-off, saddle point, game value*

Field of research: Applied Mathematical economics

I. INTRODUCTION

Economists use the word rational in a narrow way. To an economist, a rational actor is someone who makes decisions that maximize her (or his) preferences subject to constraints imposed by the environment. So, this actor knows her preferences and knows how to go about optimizing. It is a powerful approach, but it probably is only distantly related to what you mean when you think of yourself as rational. Decision theory describes the behavior of a rational actor when her actions do not influence the behavior of the people around her. Game theory describes the behavior of a rational actor in a strategic situation. Here decisions of other actors determine how well the first actor does. Economists use game theory to examine the best strategy a firm can adopt for each assumption about its rivals' behavior.

II. LITERATURE REVIEW

Several factors make game theory a useful, comprehensive tool for teaching principles of microeconomics. First, game theory is generally accepted as a standard microeconomic tool. Therefore, most instructors should be familiar with (and comfortable teaching) basic game theory. Virtually all principles of economics textbooks devote some space to game theory, usually in the chapters covering oligopoly theory (for example, see McEachern 2006; Frank and Bernanke 2006; Colander 2004; McConnell and Brue 2005). However, a handful of introductory economics textbooks apply game theory to other topics, including information theory (Frank and Bernanke 2006).

Creating strategy is based not only on the technical aspects of strategy, such as SWOT analysis and business planning, but also on the potential ethical and cultural ramifications of taking a particular action (Besanko et al. 2004).

An experimental analysis for testing generation of random series in two person games is presented in Rapoport and Budescu (1997).

Walker and Wooders (1999) present an empirical study that shows how serve-andreturn plays by several tennis champions are consistent with the minimax hypothesis.

The experimental paper by Budescu and Rapoport (1994) analyzes the differences in generating random sequences respectively in one and two-person games.

The experimental task is an iterated two-outcome zero-sum game. Subjects play a variation of O'Neill's experimental design introduced by Shachat, 1995.

After World War II, most scholars worked on developing quantitative game theory methods; and this trend still persists today (Hipel and Obeidi, 2005).

III. MATERIALS AND METHODS

The tools being used to analyze the behavior of customers in rural shops (30 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. For selecting the respondents, a convenience sampling technique was used in this study. In order to collect data, 40 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. Open questions are employed to open up for a conversation with the 40 respondents (shopkeepers), to reveal their unique experiences of the strategies taken by them. Among them 30 respondents strategies were zero-sum game strategies and the rest were non-zero sum game strategies. Here, only zero sum game strategies have been employed.

IV. DATA ANALYSIS

The interviews have been recorded to store as much information as possible so full attention could be directed to the respondent. The interviews are carefully listened to and each interview is written down as detailed reviews and frames the experiences told by the respondents. The interpreter checked the review so that no misunderstandings between him and the researcher had occurred. The language was rather poor during the interviews, so therefore no detailed transcriptions of them were made, as it was considered not fruitful. Instead the reviews are carefully written in order to maintain the respondents' stories the way they are told as much as possible.

V. RELATED CONCEPTS

5.1 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.

●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.

5.2 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.

5.3 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) x 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).(Jackson & Mclver)

5.4 Game theory:

Game theory is a study of strategic decision making. More formally, it is "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers" (Roger B. Myerson ,1991).

"The essence of strategic thinking is the ability to put yourself in other's shoes and trying to figure out what they will do." (Polak ,2007)

Game theory is essentially the mathematical study of competition and cooperation. It illustrates how strategic interactions among players result in overall outcomes with respect to the preferences of those players. Such outcomes might not have been intended by any player (Stanford Encyclopedia of Philosophy, 2006).

5.5 Zero-Sum Games

The individual most closely associated with the creation of the theory of games is John von Neumann, one of the greatest mathematicians of the 20th century. Although others preceded him in formulating a theory of games - notably ´Emile Borel - it was von Neumann who published in 1928 the paper that laid the foundation for the theory of two-person zero-sum games. Von Neumann's work culminated in a fundamental book on game theory written in collaboration with Oskar Morgenstern entitled *Theory of Games and Economic Behavior*, 1944. Other discussions of the theory of games relevant for our present purposes may be found in the text book, *Game Theory* by Guillermo Owen, 2nd edition, Academic Press, 1982, and the expository book, *Game Theory and Strategy* by Philip D. Straffin, published by the Mathematical Association of America, 1993. The theory of von Neumann and Morgenstern is most complete for the class of games called two-person zero-sum games, i.e. games with only two players in which one player wins what the other player loses. These notes describe a simple class of games called two-player zero-sum games. Zero-sum games refer to games of pure conflict. The pay-off of one player is the negative of the pay-off of the other player. This formulation is probably appropriate for most parlor games, where the outcomes are either win, lose, or draw (and there is at most one winner or loser). Maybe it describes war. It is a restrictive assumption and is not appropriate to most economic applications, where there is a strong component of common interests mixed with the conflict.

We will show that in such games:

●An Equilibrium always exists;

●All equilibrium points yield the same pay-off for all players;

●The set of equilibrium points is actually the Cartesian product of independent sets of equilibrium strategies per player.

Definition: The *strategic form*, or *normal form*, of a two-person zero-sum game is given by a triplet (X, Y, A), where

(1) X is a nonempty set, the set of strategies of Player I

(2) Y is a nonempty set, the set of strategies of Player II

(3) A is a real-valued function defined on $X \times Y$. (Thus, $A(x, y)$ is a real number for every $x \in X$ and every $y \in Y$.)

The interpretation is as follows. Simultaneously, Player I chooses $x \in X$ and Player II chooses $y \in Y$, each unaware of the choice of the other. Then their choices are made known and I wins the amount $A(x, y)$ from II. Depending on the monetary unit involved, $A(x, y)$ will be cents, dollars, pesos, beads, etc. If A is negative, I pays the absolute value of this amount to II. Thus, $A(x, y)$ represents the winnings of I and the losses of II. This is a very simple definition of a game

5.6 Payoff

A payoff is a number, also called utility, which reflects the desirability of an outcome to a player, for whatever reason. When the outcome is random, payoffs are usually weighted with their probabilities. The expected payoff incorporates the player's attitude towards risk.

5.7 Saddle points: Occasionally it is easy to solve the game. If some entry *aij* of the matrix ***A*** has the property that

(1) *aij* is the minimum of the *i*th row, and

(2) *aij* is the maximum of the *j*th column, then we say *aij* is a saddle point. If *aij* is a saddle point, then Player I can then win at least *aij* by choosing row *i*, and Player II can keep her loss to at most *aij* by choosing column *j*. Hence *aij* is the value of the game.

5.8 Basic Assumption of 2 person 0-sum games:
Each player chooses a strategy that enables him to do the best he can given that the opponent knows the strategy he is following.

Row Player's Strategy	Col 1	Col 2 (Column player's strategy)	Col 3	Row minimum
Row 1	4	4	10	4
Row 2	2	3	1	1
Row 3	6	5	7	5
Column maximum	6	5	10	

If Row Player (RP) chooses R1, the assumption implies that the Column Player (CP) will choose C1 or C2 and hold the RP to a reward of 4 (the smallest number in row 1 of the game matrix). If RP chooses R2, CP will choose C3 and hold the RP's reward to 1 (the smallest-minimum in the second row). If RP chooses R3 then CP will allow him 5. Thus, the assumption →RP should choose the row having the largest minimum. Since max (4, 1, 5) → 5, RP chooses R3. This ensures a win of at least max (row minimum) = 5

If the CP chooses C1, the RP will choose R3 (to maximize earnings). If CP chooses C2 the RP will choose R3. If the CP chooses C3 the RP will choose R1 (10 = max (10, 1, 7)). Thus the CP can hold his losses to min (column max) = min (6, 5, 10) = 5 by choosing C2.
Thus, the RP can ensure at least 5 (win) and the CP can hold the RP's gains to at most 5. Thus, the only rational outcome of this game is for the RP to win 5. The RP cannot expect to win more because the CP (by choosing C2) can hold RP's win to 5.

The game matrix we have analyzed satisfies the **SADDLE POINT CONDITION** property

(Maximum over all rows) (Row minimum) = (Minimum over all columns) (Column maximum) (1)

Any 2 person 0-sum game (2p0sg) satisfying (1) is said to have a SADDLE POINT. If a 2p0sg has a saddle point the RP should choose any R strategy attaining the maximum on the LHS of (1) and a CP should choose a C strategy attaining the minimum on the RHS. In the game considered a saddle point occurred at R3 and C2. Therefore, saddle point = (3, 2). If the game has a saddle point we call the common value to both sides of (1) the VALUE (v) of the game. In the above case v = 5.

VI. EMPIRICAL EVIDENCE

Here 15 observations have been employed where the same strategies were followed. As the shops are local shops, customers are fixed per day. Two shopkeepers has set price of a product at higher price than initial price. But one shopkeeper betrayed with another and decreased the price than initial price. In this situation, in some cases high price setter will be winner and low price setter will be loser. Again, in some cases, high price setter will be loser and low price setter will be winner.

6.1 Assumption:

1) There are only two players in an observation around one square kilometer area.
2) The costs are unchangeable as they are not known to future occurrences.

6.2 Observations:

Observation 1: Item: patties

	1st shopkeeper	2nd shopkeeper
Initial Price (per unit)	Tk 8	Tk 8
Customer (per day)	15	15
Revenue	Tk 120	Tk 120
New price	Tk 10	Tk 7
Customer (per day)	10	20
Revenue	Tk 100	Tk 140
Gain/Loss	Loss : Tk 20	Gain : Tk 20

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-20]
Saddle Point: (1,1)
Game value, V = -20

Observation 2: Item: Brinjal

	1st shopkeeper	2nd shopkeeper
Initial Price (per kilogram)	Tk 30	Tk 30
Customer (per day)	20	20
Revenue	Tk 600	Tk 600
New price (per kilogram)	Tk 33	Tk 28
Customer (per day)	16	24
Revenue	Tk 528	Tk 672
Gain/Loss	Loss : Tk 72	Gain : Tk 72

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-72]
Saddle Point: (1,1)
Game value, V = -72

Observation 3: Item: Cigarette (More Brand)

	1st shopkeeper	2nd shopkeeper
Initial Price (per unit)	Tk 9	Tk 9
Customer (per day)	15	15
Revenue	Tk 135	Tk 135
New price	Tk 11	Tk 8
Customer (per day)	10	20
Revenue	Tk 110	Tk 160
Gain/Loss	Loss : Tk 25	Gain : Tk 25

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-25]
Saddle Point: (1,1)
Game value, V = -25

Observation 4: Item: Cigarette (Benson brand)

	1st shopkeeper	2nd shopkeeper
Initial Price (per unit)	Tk 10	Tk 10
Customer (per day)	20	20
Revenue	Tk 200	Tk 200
New price	Tk 13	Tk 8
Customer (per day)	16	24
Revenue	Tk 208	Tk 192
Gain/Loss	Gain : Tk 8	Loss : Tk 8

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [8]
Saddle Point: (1,1)
Game value, V = 8

Observation 5: Item: Potato Chop

	1st shopkeeper	2nd shopkeeper
Initial Price (per unit)	Tk 6	Tk 6
Customer (per day)	20	20
Revenue	Tk 120	Tk 120
New price	Tk 9	Tk 4
Customer (per day)	16	24
Revenue	Tk 144	Tk 96
Gain/Loss	Gain : Tk 24	Loss : Tk 24

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [24]
Saddle Point: (1,1)
Game value, V = 24

Observation 6: Item: Egg Chop

	1st shopkeeper	2nd shopkeeper
Initial Price (per unit)	Tk 12	Tk 12
Customer (per day)	18	18
Revenue	Tk 216	Tk 216
New price	Tk 14	Tk 11
Customer (per day)	12	24
Revenue	Tk 168	Tk 169
Gain/Loss	Loss : Tk 48	Gain : Tk 48

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-25]
Saddle Point: (1,1)
Game value, V = -25

Observation 7: Item: Banana

	1st shopkeeper	2nd shopkeeper
Initial Price (per pair)	Tk 10	Tk 10
Customer (per day)	20	20
Revenue	Tk 200	Tk 200
New price	Tk 16	Tk 6
Customer (per day)	16	24
Revenue	Tk 256	Tk 144
Gain/Loss	Gain : Tk 56	Loss : Tk 56

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [56]
Saddle Point: (1,1)
Game value, V = 56

Observation 8: Item: cup of tea

	1st shopkeeper	2nd shopkeeper
Initial Price (per cup)	Tk 5	Tk 5
Customer (per day)	30	30
Revenue	Tk 150	Tk 150
New price (per cup)	Tk 7	Tk 4
Customer (per day)	20	40
Revenue	Tk 140	Tk 160
Gain/Loss	Loss : Tk 10	Gain : Tk 10

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-10]
Saddle Point: (1,1)
Game value, V = -10

Observation 9: Item: Vegetable Curry

	1st shopkeeper	2nd shopkeeper
Initial Price (per bowl)	Tk 15	Tk 15
Customer (per day)	18	18
Revenue	Tk 270	Tk 270
New price (per bowl)	Tk 17	Tk 14
Customer (per day)	12	24
Revenue	Tk 204	Tk 336
Gain/Loss	Loss : Tk 66	Gain : Tk 66

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-66]
Saddle Point: (1,1)
Game value, V = -66

Observation 10: Item: Shingara (a Bengali snack)

	1st shopkeeper	2nd shopkeeper
Initial Price (per unit)	Tk 3	Tk 3
Customer (per day)	21	21
Revenue	Tk 63	Tk 63
New price	Tk 5	Tk 2
Customer (per day)	14	28
Revenue	Tk 70	Tk 56
Gain/Loss	Gain: TK 7	Loss : Tk 7

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [7]
Saddle Point: (1,1)
Game value, V = 7

Observation 11: Item: Candle

	1st shopkeeper	2nd shopkeeper
Initial Price (per unit)	Tk 6	Tk 6
Customer (per day)	9	9
Revenue	Tk 54	Tk 54
New price	Tk 8	Tk 5
Customer (per day)	6	12
Revenue	Tk 48	Tk 60
Gain/Loss	Loss : Tk 6	Gain : Tk 6

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-6]
Saddle Point: (1,1)
Game value, V = -6

Observation 12: Item: Potato

	1st shopkeeper	2nd shopkeeper
Initial Price (per kilogram)	Tk 25	Tk 25
Customer (per day)	30	30
Revenue	Tk 750	Tk 750
New price (per kilogram)	Tk 27	Tk 24
Customer (per day)	20	40
Revenue	Tk 540	Tk 960
Gain/Loss	Loss : Tk 210	Gain : Tk 210

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-210]
Saddle Point: (1,1)
Game value, V = -210

Observation 13: Item: Rice (Jirashai)

	1st shopkeeper	2nd shopkeeper
Initial Price (per kilogram)	Tk 40	Tk 40
Customer (per day)	21	21
Revenue	Tk 840	Tk 840
New price (per kilogram)	Tk 44	Tk 37
Customer (per day)	18	24
Revenue	Tk 792	Tk 888
Gain/Loss	Loss : Tk 48	Gain : Tk 48

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-48]
Saddle Point: (1,1)
Game value, V = -48

Observation 14: Item: Onion

	1st shopkeeper	2nd shopkeeper
Initial Price (per kilogram)	Tk 32	Tk 32
Customer (per day)	14	14
Revenue	Tk 448	Tk 448
New price (per kilogram)	Tk 34	Tk 31
Customer (per day)	12	16
Revenue	Tk 432	Tk 464
Gain/Loss	Loss : Tk 16	Gain : Tk 16

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-16]
Saddle Point: (1,1)
Game value, V = -16

Observation 15: Item: Rice (Basmati)

	1st shopkeeper	2nd shopkeeper
Initial Price (per kilogram)	Tk 50	Tk 50
Customer (per day)	7	7
Revenue	Tk 350	Tk 350
New price (per kilogram)	Tk 54	Tk 47
Customer (per day)	6	8
Revenue	Tk 324	Tk 376
Gain/Loss	Loss : Tk 26	Gain : Tk 26

Shopkeeper 2
Therefore, pay off matrix, Shopkeeper 1 [-26]

VII. RESULTS

We have shown that in 2-player zero sum game the gain-ceiling for shopkeeper 1 is equal to the loss-floor for shopkeeper 2. We denote this value simply by *V* and call it the *value of the game*.

VIII. CONCLUSION

Game theory can provide insights for understanding or resolving strategy conflicts which often are multi-criteria multi-decision-makers problems. It sometimes can reflect and address socio-economic characteristics of business problems even without detailed quantitative information and without a need to express performances in conventional economic and financial terms. Game theory can predict if the optimal resolutions are reachable and explain the decision makers' behavior under specific conditions. By simple examples of 1x1 games, it was discussed how game theory results might not be optimal for the whole system and how decision makers can make decisions based on self interests and the problem's current structure. The examples presented here are very simple. But, understanding the basic concepts of game theory allows for modeling complicated problems to gain valuable insights into strategic behaviors of the shopkeepers.

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APPENDICES:

Information about respondents:

Observations	Address
Observation 1: Shopkeeper 1: Md Jamal Shopkeeper 2: Md Khair	Village: Razar howla, P.O: Oskhali, P.S: Hatiya, District: Noakhali
Observation 2: Shopkeeper 1: Rana Das Shopkeeper 2: Kiron Das	Village: Chorlatia, P.O: Afazia Bazar, P.S: Hatiya, District: Noakhali
Observation 3: Shopkeeper 1: Rupak Das Shopkeeper 2:Sajal Das	Village: Laxmidia, P.O: Oskhali, P.S: Hatiya, District: Noakhali
Observation 4: Shopkeeper 1:Yusuf Miah Shopkeeper 2: Barkat Ullah	Village: East Sonadia, P.O: Bangla Bazar, P.S: Hatiya, District: Noakhali
Observation 5: Shopkeeper 1:Sanjoy dutta Shopkeeper 2:Goutam Dey	Village: Musapur, P.O: Pondither hat, P.S: Sandwip, District: Chittagong
Observation 6: Shopkeeper 1:Md Bari Miya Shopkeeper 2:Jamal Hossain	Village: Haramia, P.O: Anam Nahar, P.S: Sandwip, District: Chittagong
Observation 7: Shopkeeper 1:Mithun Lal Shopkeeper 2:Jiban Shil	Village: Bauria, Post Office: Nazir Hat, P.S: Sandwip, District: Chittagong
Observation 8: Shopkeeper 1:Md. Ochi Uddin Shopkeeper 2:Abul Hossain	Village: Mag Pukur Par, P.O: SitaKunda, P.S: Sitakunda, District: Chittagong
Observation 9: Shopkeeper 1:Joynal Abedin Shopkeeper 2:Ismail Hossain	Village: Nayantola, P.O: Barura, P.S: Barura, District: Comilla
Observation 10: Shopkeeper 1:Md Hasan Shopkeeper 2: Ranjit Kanti Das	Village: Kemtali, P.O: Kushbush, P.S: Barura, District: Comilla
Observation 11: Shopkeeper 1:Keshab Shil Shopkeeper 2:Rajesh Ghosh	Village: Bortala, P.O: Barura, P.S: Barura, District: Comilla
Observation 12: Shopkeeper 1: Md. Shahabuddin Shopkeeper 2: Ajoy Chandra Das	Village: West Chilonia, P.O: Hazir Bazar, P.S: Feni, District: Feni
Observation 13: Shopkeeper 1: Osman Goni Shopkeeper 2:Toukir Ahmed	Village: Mondakini, P.O: Nazir hat, P.S: Fatickchari, District: Chittagong.
Observation14: Shopkeeper 1: Jakir Hossain Shopkeeper 2: Saddam Hossain	Village: Jujkhola, P.O: Narayanhat, P.S: Bhujpur, District: Chittagong
Observation15: Shopkeeper 1: Md. Aman Shopkeeper 2: Md. Salahuddin	Village: East Joabil,Vanga dighir par, P.O: Boidder Hat, P.S: Bhujpur, District: Chittagong