MODELLING HEALTH OUTCOME: A GAME THEORY PERSPECTIVE

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ABSTRACT

Medical outcome can be described as a two-way interaction involving interactive decision making. Game theory deals with rational choices under the interactive decision making environment. Models of Game theory provide insights into the possible underlying dynamics of social interaction. In the present paper, an attempt is made to employ the game theory in the field of health outcome. Further, the Game theory models have potential to provide basis for future empirical work in the area of health economics.

Keywords: Modelling Health Outcome, Game Theory, Medical Outcome

INTRODUCTION

The medical outcome can be best understood as a two-way interaction of agents, and Game theory *can* be regarded as an appropriate conceptual tool for describing and analysing interactive decision making under such circumstances. Following the seminal work by von Neumann in the 1920's, the Game theory has emerged as an important area which has wide range of applications in business and economics after the publication of von Neumann and Morgenstern (1944). Its applications in the social and behavioural sciences emerged after the work of Luce and Raffia (1957). Its importance in economic sciences proliferated after the award of Nobel prizes to the game theorists in 1994.The use of the game theory in modelling the decision making in economics, in particular, is found in Camerer (2003) and Sugden (1991). In the area of health care where the behavioural interaction is essential for medical outcome, Hockstra and Miller (1976) were first to highlight the role of game theory in decision making process. Theoretical and experimental literature on game theory focus *inter alia* on factors responsible for promoting cooperation, reciprocity and trust which could be applied to developing an understanding of cooperation and trust in the area of medical care. Recently, the Game theoretical perspective has been found useful in many aspects of interactive decision process in the area of health care, in the present paper our focus is on two major areas namely physicians' care and economic epidemiology in the particular context of HIV/AIDS. Plan of the paper is as follows. After introducing the key elements of Game theory in the next section, we briefly summarize some of the Game theory models relevant for physicians' care and epidemics.

Game Theory: Conceptual Framework

Analysis of economic behaviour where there are more than one decision makers is known as Game Theory. This is the study of economic behaviour of two or more decision makers (called players), and each player has two or more decisions (called *strategies*) to choose from.

Each player is assumed to have clear preferences among possible outcomes in which conflict and cooperation play important role. The sources and nature of preferences and beliefs are not important, but it is assumed that the people generally seek to do best for themselves as per their belief. Game theory seeks to answer the question: What is the likely outcome of a game? The theory seeks to identify "likely outcome" of a Game using what is known as Nash equilibrium. The Nash equilibrium suggests that each player chooses his best strategy that gives him/her the highest payoff, because this outcome is self-enforcing. If each party chooses its respective Nash equilibrium, then expectation equals outcome-expected behavior and actual behavior converge. Game theory in a sense provides a means of abstracting the fundamental structure of an interaction and representing it in terms of a strategic game. Game Theory is concerned with decisions in which the outcomes depend purely on the actions of two or more decision makers called *players*. Each player has two or more ways of acting, called *strategies*.

Models of Game Theory

The Prisoner's Dilemma Game: Most important of all strategic games, the Prisoner's dilemma game is standard starting model of a two- person interaction involving cooperation and competition, or trust and betrayal. Let us assume that two prisoners are held in separate cells for a serious crime that they did in fact commit together. The prosecutor, however, has only enough hard evidence to convict them of minor offence, for which the penalty is say one year imprisonment. Each prisoner is told that if one confesses while the other remains silent, the confessor will get scot free while the other spends 20 years in jail. If both confess, they will get an intermediate sentence say 5 years. The two prisoners are not allowed to communicate that is non-cooperative game.

Table.1: Structure of Prisoner's dilemma

Player I	Player II	
	C (Cooperate)	D (Defect)
C(Cooperate)	C,C	C,D
D(Defect)	D,C	D,D

For such a two player game, a Nash equilibrium is defined as a pair of strategies that are best actions to each other[1].The unique Nash equilibrium in the Prisoner's dilemma game is joint defection(D,D),with both prisoners defecting or disclosing information. However, the situation is different when consider interactions that are expected to continue indefinitely in the future. In this context it is possible to find cooperative strategies that are Nash equilibrium. From a purely game theoretic model, cooperation is never a rational strategy because it assumes that there is a conflict between self-interest and benefits achieved through mutual cooperation. There are three elements common to all games: the players, the list of possible strategies; and the pay-offs that correspond to each combination of strategies.

The Assurance Game: The Prisoner's dilemma has some limitations. First, it is applicable only if there is single play, second it is applicable if quality of the outcome is not important and the two players are interchangeable in the sense the pay-off each player is equal. In health outcome, there are situations when stakes are higher for one player. In other words the payoffs have greater impact on one player than the other. The Assurance game model deals with the situation where cooperation may involve an element of risk. In such situations, both

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[1] Best action being a strategy that yields the best outcome to the player choosing it, given the co-player's strategy.

players need assurance or trust to risk cooperation. In many of the health outcomes mutual cooperation is required and hence coordinated games may be a better representation. If the cooperation involves an element of risk then Sen (1969) proposed a modification to the Prisoner's dilemma considering an element of risk in the outcome. In such a situation, (C, C) outcome is a Nash equilibrium if each player is confident that the other will cooperate in future interaction and the game is not one time.

The Centipede Game Model: To model interactions between a pair of players which are repeated a certain number of times; Rosenthal (1981) suggested the Centipede game. The game stops if either player defects at any point. Thus defection is always rational and Nash equilibrium is the one when player I defects on the very first move.

REVIEW OF LITERATURE

Applications of Game Theory in Health Outcome

In health economics, the health outcome is the end result of health care. There are many types of interactions involved in health care between two individuals. In this section an attempt has been made to apply the models of game theory in the formulation of health outcome. We consider only two situations for the purpose of applying Game theory; first physician- patient interaction and second social interaction of people in the context of HIV transmission.

Game Theory and Physicians' Care- In health care physicians normally act as agent for a consumer where they have great deal more knowledge of the demand for medical care than the consumer himself. This is a common phenomenon when parties have unequal knowledge and this situation is referred to as asymmetric information. In health care, the physician (or health care provider) is identified as *agent* and the patient as the *principal*. The Prisoner's Dilemma is most suited to the physicians' care particularly in the context of HIV/AIDS. Consider an adult patient who requires but does not want medical attention. At the request of friends, he visits a doctor to treat his condition. From the reports the physician concludes the adult has loss of appetite, weight loss, and elevated cholesterol, sweating, and risk factors for the disease. Models of Game Theory in medical consultation have been reviewed in Tarrant, Stokes and Colman (2004).

The doctor has two choices when he meets with the patient. He can choose whether to spend 5 minutes to prescribe mildly effective medicines (*D*) or he can spend 15 minutes and describe very effective lifestyle changes (*C*).The adult also has two choices when he meets the doctor. He can either choose to follow the doctor's recommendation (*C*) or he can instead ignore the advice and find a second opinion (*D*). From these choices we observe four possible outcomes:

- Both cooperate: doctor gives lifestyle advice and patient complies (C,C)
- Only doctor cooperates: doctor gives lifestyle advice and patient ignores it (C,D)
- Only patient cooperates: doctor gives medicine and patient takes it (D,C)
- No one cooperates: doctor gives medicine and patient does not take it (D,D)

The best outcome is that both cooperate (C, C) this is the situation where the doctor gives the best advice and the patient follows it. The patient will want to find a second opinion regardless. If the doctor prescribes ineffective medicine, he is better off ignoring the advice (D, D). If the doctor gives the good advice, then again, the patient can be better by confirming it from another doctor as a double check (C, D).Finally, the doctor gives medicines and the patient follows it(D,C),The underlying structure of the Prisoner's Dilemma game is presented below in Table 2.

Table 2: Structure of Physician-Patient interaction

Doctor	Patient	
	C(Cooperate)	D(Defect)
C(Cooperate)	C,C	C,D
D(Defect)	D,C	D,D

In reality, patients need to be skeptical, given the economics of health care. This is a system where doctors are typically paid for activity rather than outcomes. Even though doctors are generally good people, the system often results in unnecessary drug prescriptions, tests, and surgeries. This phenomenon is known as Supplier-Induced Demand. In most developing countries and India is no exception it is generally observed that in maternity cases patient is generally recommended surgery which may not be required. And along the way, the patient-doctor relationship is strained. Game theory may be employed to study trust between physicians and patients and thus may serve as a useful tool for understanding strategic interaction and creating better outcomes in medical care.

Game Theory and HIV/AIDS Prevalence- In many cases, it has been observed that local pattern in some African countries influence understanding of AIDS and attitude of people towards sex (Folland *et al*., 2010). Several attempts have been made to study prevalence of HIV/AIDS in Africa (See, for Botswana Ray and Sinha, 2011). Higher prevalence rate of HIV in Africa is mainly due to its high transmission rate and high transmission is because of social interaction of two individuals (Oster, 2005). The HIV/AIDS in sub-Saharan Africa in general and in Botswana in particular is mainly due to sexual behavior and mother-to-child (Esilaba, 2003). Ntseane and Preece (2005) suggest that both family and society play a key role in sexual matters related to HIV. Empirical studies suggest that in spite of the fact that the people have information about HIV/AIDs, some (HIV)-infected individuals continue to engage in unprotected sex with uninfected partners. This behaviour demonstrates that some individuals place self-gratification above public health. Therefore, here we present a simple model of the sexual behaviour of the HIV+ as well as the HIV- individuals to employing a game theoretical framework so that the effects of such behaviour on the spread of HIV through a population can be studied.

About half the world's HIV positive population today is made up of young people aged 15-24. An estimated 12.5 million adolescents living with HIV/AIDS are expected to escalate, with an increasing proportion of new infections occurring in young people (UNAIDS, 2008). Despite the improvement in health services, HIV/AIDS and other related diseases remain a challenge to economic growth in Sub-Saharan Africa and particularly in Botswana which is regarded as an exceptional African country. A constitutional democracy since its independence with effective institutions of governance, Botswana grew rapidly, growth mainly driven by the diamond discovery in early 1970s. Botswana has reaped the benefits of a responsible and far-sighted leadership. The problem of HIV/AIDs was recognized[2] early when the first case was diagnosed in the country (Allen and Heald, 2004). The figure 1 below shows that during 2004 -2008 the prevalence rate of HIV in Botswana has declined in the

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[2] The first national campaign in 1988 focused on radio messages, car bumper stickers and T shirts to get the message across (Ingstad,1990)

younger age groups, attaining the peak level of 40.2 percent and 40.6 percent in the Age group 30 -34 years has in 2004 and 2008, respectively (CSO, 2009)[3].

Figure 1: HIV/AIDS Prevalence Rate in Botswana by age groups (2004 and 2008)
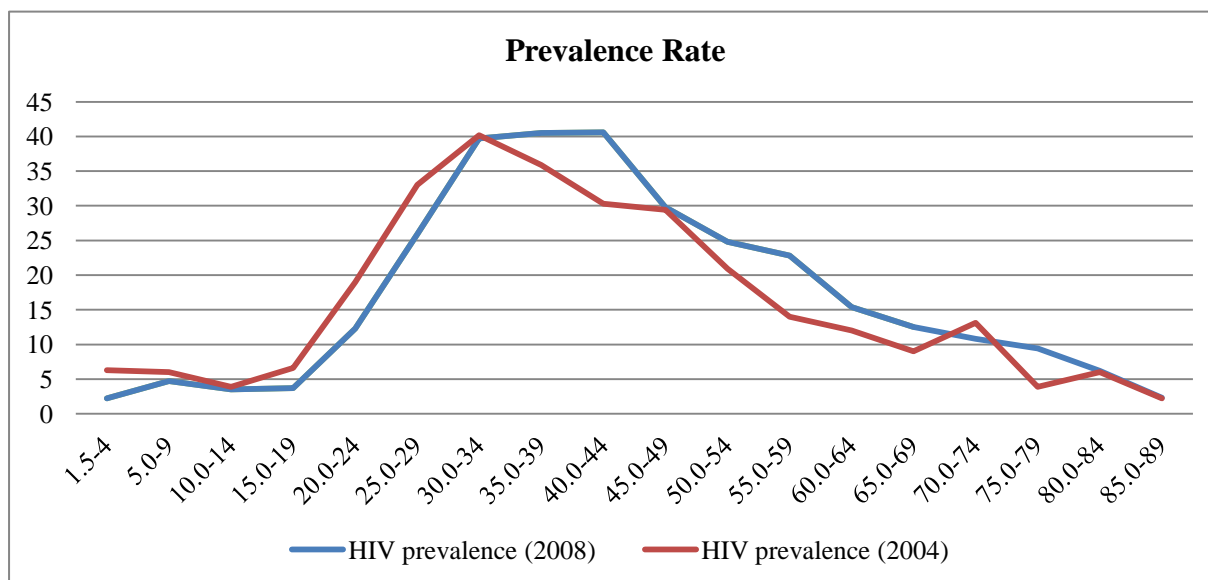
Source: Botswana HIV/AIDS Impact Survey II (2004) and Botswana HIV/AIDS Impact Survey III (2008)

For the older population, the prevalence rate is high in 2008 as compared to 2004. The national prevalence rate is estimated at 17.6 percent in 2008 which is higher as compared to 17.1 percent in 2004.

Adolescents are identified as a highly vulnerable group because of their proclivity towards high-risk sexual behaviours (UNFPA, 2002). Often, such adolescents are not fully aware of the consequences of their actions, or have misconceptions towards HIV/AIDS. In most of the countries in Asia and Africa, changing cultural norms have led to a growing trend of early sexual activity and low use of contraception among young people (UNICEF, 2005). In these countries, adolescents are becoming sexually active at an earlier age; increasingly, they do so without taking protective measures. Further, they do not have information on their sexual outcomes.

Recent advances in medical treatment for people infected with HIV have dramatically reduced the annual rate of Acquired Immunodeficiency Syndrome (AIDS) cases and AIDS-related deaths. However, at the same time, the prevalence rate has not dropped considerably. Despite a marked increase in public awareness of HIV transmission, not much change in HIV high-risk behaviours is observed. This suggests that many people continue to engage in HIV-transmitting behaviour, including unprotected (high-risk) sex, despite the widely accepted fact that condoms greatly reduce the likelihood of HIV transmission. Up till today, there is still no preventive vaccine or medical cure for this deadly disease; therefore, efforts to change high-risk behaviours remain the only available means to prevent HIV infection.

The fact that the dissemination of HIV information alone is not going to control the spread of the epidemic, and it has led to the rise of behavioural studies to model and understand

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[3] The Botswana AIDS Impact Survey (BAIS) III is the third sexual behavioural survey and was conducted under the auspices of the Central Statistics Office's Programme of Household Surveys. The BAIS III fieldwork took place between 15th July and 22nd October 2008.

people's high-risk behaviours, and consequently, to attempt to modify such behaviours as preventive measures. We seek to describe how a game theoretical framework can be employed to model the sexual behaviour of the HIV+ as well as the HIV- individuals and study the effects of such behaviour on the spread of HIV through a population. In this review, we will also discuss the advantages of using a game theory model over the other epidemic models.

The HIV Problem and the Significance of Behavioural Modelling-The high-risk sexual behaviour can be analyzed using a number of theoretical models, including the 'Health Belief Model', the 'Communication Perspective', and the 'Theory of Reasoned Action'. However, these models fail to address the fundamental problems of trust, deception, and behavioural incentives that are resolved in the game theoretical model.

Modelling Sexual Behaviour- The Game Theoretical Approach-The Game theoretical models have developed as an extension of various bevioural models, overcoming their limitations. The model involves is an extension of the Prisoner's dilemma when the game is repeated, involve an element of risk and with unequal payoffs. Consider

- the two-person of sexual behaviour
- the idea of perceived value of a particular outcome combined with a subjective expectation that this outcome will occur
- the 'get-to-know-your partner' (or trust) strategy while taking into consideration the possibilities of betrayal, and
- the use of the utility theory by treating actors as rational decision-makers.

 It considers only the perceived costs and benefits of the actors' decisions. It also allows for concise description of the available choices, and assumes that the players will maximize their expected utility given the preferences and the likely actions of others. Furthermore, the game theoretical model can be extended from the micro-level between 2 individuals to a macro-level involving a population as a whole via agent simulation, therefore it is not only capable of describing the interactions of two or more people in an interdependent way, it can offer greater insights into how HIV can spread in a population through sexual transmission. In this context, the Game involves two players randomly selected from a population comprising of HIV-infected and uninfected individuals. To protect themselves, HIV− individuals need to know their partners and what kind of output (sex) should they have. Hence, there are three possible sets of scenarios: a set of two HIV+ players, a set of two HIV− players, and a set of HIV+/HIV− players.

ASSUMPTIONS OF THE MODEL

1. HIV+ individuals will always prefer unprotected sex to protected sex under all circumstances, and will prefer any type of sex to no sex at all. (There are no altruistic HIV+ players who would attempt to sort the HIV+ and HIV− players and choose to engage only in protected sex with the HIV− players).
2. HIV− individuals will always prefer to have protected sex with HIV+ partners, always prefer to have unprotected sex with other HIV− partners, and always prefer no sex at all to unprotected sex with HIV+ partners.
3. The players will choose a choice in which they can maximize their personal expected utility, given their beliefs about the context in which they are acting.
4. All the players know the preferences (listed as assumptions 1 and 2, above) of all the HIV+ and HIV− players.
5. All the players know their HIV status.

6. Sexual behaviour is the same regardless of culture differences, and heterosexual/homosexual couplings.

Simple Model of Game-This game involves players 1 and 2, both of whom can be HIV+ or HIV−. They have a common shared belief that the other may be HIV+ but they are not sure. The risk associated with outcome is represented by the probability that the other is HIV+ is p. Notice that the game operates under the condition of limited information. Player 1 offers to have either Protected Sex (PS) or Risky Sex (RS), and Player 2 counter-offers either Protected or Risky Sex. Player 1 either accepts the offer or ends the interaction with No Sex (NS). If Player 1 accepts the offer of Player 2, the pair will have the kind of sex offered by Player 2. Table 3 presents the structure of two individuals

Table 3: Structure of interactions of two individuals

Player I	Player II	
	HIV+	HIV-
HIV+	C,C	C,D
HIV-	D,C	D,D

The preferences of the players depend on whether they are HIV+ or HIV−. Table 4 shows the preferences of Player I under various conditions of complete information. This model portrays some important features of real-life sexual behaviour. Like in real life, the model allows for negotiation and for individuals to keep their actual HIV status from each other's. This actually sums up assumptions 1 and 2.

Table 4: Preferences of a given Player I based on the status of Player II

HIV Status		Preferences of Player I
Player I	Player II	
HIV+	HIV+	RS > PS > NS
HIV+	HIV−	RS > PS > NS
HIV−	HIV+	PS > NS > RS
HIV−	HIV−	RS > PS > NS

The Risky Sex Game-In the game model above, we assumed that both the HIV+ and HIV− players will react in different ways and can be clearly identified according to their actions. Based on this we define two types of equilibriums. First one is termed as the 'separating equilibrium'; presenting it probabilistically, it means the initial belief that the other player is HIV+ changes during the interaction period. In a 'separating equilibrium', if Player I is HIV+, he/she will always offer RS. Then a HIV+ Player II will counter-offer RS while a HIV− Player II will offer PS. Player I will accept either one. In the case that if Player I is HIV−, he will always offer PS no matter what he thinks Player II's HIV status is. Player II, regardless of HIV status, will counter-offer and accept PS. According to this deduction whereby the signal separates Player I, we see that if the population of HIV+ individuals is low, then PS will be the more prevalent manner of sexual interaction. However, it is not so in reality. This leads us to the second type of equilibrium – the 'pooling equilibrium'. 'Pooling equilibrium'

is one which models individuals in real-life situations, where HIV+ and HIV- individuals would try to hide their information by acting in ways that are not predictable. In this equilibrium, the actions of the players do not reveal his/her HIV status. Player II does not know anything about the status of Player I, after Player I has made an initial offer. The safest for Player II would be to assume that Player I is infected, and counter-offers a choice based on his/her own status. However, in this provided analysis, it is assumed that both players can pool – both offers by Player I and Player II do not reveal anything about themselves. Hence, HIV+ and HIV− players act in the same way and if this occurs, it means that either the HIV+ or the HIV− player is not being truthful about his or her HIV status. This game is also termed the 'risky sex game', because it involves risk-taking for the uninfected players.

CONCLUSION

Game theory is an important tool used in describing some of the fundamental features of health outcome. The theory has proved as a theoretical basis in the empirical analysis of health outcome facilitating to generate empirically testable hypotheses about interaction of two players. In the present paper, an attempt has been made to review applications of game theory in the analysis of interaction of players in two areas namely, patients and doctors interaction in primary medical care, and two partners in the sexual behaviour in the context of HIV/AIDS. Nash equilibrium is different in both of these games. In patient-doctor interaction the Nash equilibrium is when both defect. In the context of the HIV/AIDS, because of repetitive nature of the game and unequal payoffs, the Nash equilibrium is when both cooperate. The game theoretical models generated in the literature can be employed in the analysis of the high-risk sexual behaviours as well as the spread of sexually transmitted diseases in specific populations.

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