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# Modelling Digital And Value Flows In E-health: A Game-theoretic Analysis

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## Abstract

This paper describes the synthesis of field research comprising a cross-case analysis of the digital health ecosystems of Singapore and the United States. The two cases were selected using the 'purposive sampling' approach based on the sampling strategies of 'maximum variation' and 'information richness'. The insights extracted are used to derive some critical success factors for a sustainable e-health ecosystem. The new knowledge acquired through the cross-case analysis is compared with the literature for theoretical integration. The paper concludes with a brief account of some key findings.

## 1. Introduction and Overview

Each ecosystem's journey towards e-health is unique. Several factors such as the size of the country, structure of its healthcare system, political climate and socio-economic culture influence the journey. The key imperatives leading to the initiation of e-health to transform the healthcare eco-system may also vary from country to country. For instance, one of the significant factors that started Singapore on its healthcare transformation journey, was the 'silver tsunami' – a term used to refer to a rapidly aging population (Stephanie, 2017a). In the US on the other hand a key factor driving the country's healthcare transformation journey was the sky-rocketing healthcare expenditure (Stephanie, 2017b). Regardless of the unique circumstances that lead a nation to pursue e-health in order to positively transform its healthcare industry, the underlying concerns with respect to healthcare cannot be dissimilar across healthcare systems, countries or even continents. When it comes to healthcare, each ecosystem gravitates towards the common goals of improving quality, access and equity for its citizens and e-health is adopted for its promise to meet these goals.

The scholarly literature has recognized e-health as a promising strategy that can transform the healthcare ecosystem by integrating it and facilitating the flow of patient data in ways that can enhance the effectiveness and efficiency of healthcare (cf. Hill & Powell, 2009). However, facilitating such exchange of health information has always been a struggle for want of an effective model to do so (Vest et al., 2013). The challenges involved in implementing e-health on a national scale are often underestimated. These challenges are not just limited to technical issues but in fact have more to do with political and economic issues (Blank, 2012; Yaraghi, 2015).

## 2. Major Barriers to E-Health: A Game Theoretic View

The formal study of decision-making in strategic situations where several players must make choices that potentially impact the interests of the other players is called game theory (Turocy & von Stengel, 2001). The term "game" in game theory is used to formally describe a strategic situation. Game theory provides a systematic way to understand the behaviour of players in situations of interdependent fortunes (Brandenburger & Nalebuff, 1995) like in the e-health ecosystem. It is the study of conflict and cooperation among intelligent, rational entities often referred to as 'players', in their decision-making processes (Myerson, 1991). Since e-health

calls for cooperation among the players amidst conflicts, it is believed that game theory principles may be useful for an analysis of their behaviour.

A basic aspect of a game is the interdependence of the players' decisions (Dixit & Nalebuff, 2008), which, in the context of e-health, may mean a key player's freedom of choice whether or not to participate and create values in the ecosystem. Such a situation that necessitates a difficult choice among undesirable alternatives is referred to as a 'dilemma'. The typical dilemmas faced by healthcare providers during the various stages of the evolution of e-health and may be considered to fall into two categories namely (i) participation dilemmas and (ii) cooperation dilemmas. These dilemmas, if unresolved, may render e-health infeasible and unsustainable. A brief account of each of the dilemmas is given below.

### 2.1. Participation Dilemmas

These are barriers that deter healthcare providers from taking the essential first steps towards e-health, which involves making substantial investments in building EHRs. What follows is a short discussion of the participation dilemmas:

#### *2.1.1. Productivity Paradox*

The famous quip by Robert Solow, Nobel Laureate in Economics, that, "we see computers everywhere except in the productivity statistics" (Solow, 1987), still rings true after decades, especially in the context of investments in e-health. In the absence of demonstrable evidence of positive payoffs from e-health investments (Wiedemann, 2012; Bergmo, 2015), the strategy most prevalent among individual healthcare providers is defection to e-health rather than joint cooperation. This would mean that if healthcare providers are not motivated to invest in EHRs due to the productivity paradox, e-health may continue to remain a distant dream.

#### *2.1.2. Tragedy of the Digital Commons*

EHRs are the building blocks of e-health that need to be heavily invested in and created by the healthcare providers. These digital health records also need to be enabled for exchange and reuse of health data by other players in the network such as patients, payers, vendors, and other healthcare providers (Adler-Milstein & Bates, 2010), so that the benefits of e-health are harnessed in toto. In other words, in a patient-centric e-health ecosystem, health data is viewed and treated as a public good or "commons" which every stakeholder including patients and those authorized by patients can consume without necessarily contributing to it. This 'free-riding' Albanese and Fleet (1985) is reminiscent of the misaligned incentives discussed in the context of e-health and often deters healthcare providers from investing in e-health (Bandyopadhyay et al., 2012). This will only lead to a deficient or less desirable outcome for everyone, resulting in a situation referred to by Adar and Huberman (2000) as the 'tragedy of the digital commons'.

### 2.2. Cooperation Dilemmas

These dilemmas, as different from participation dilemmas, relate to such healthcare providers as have already invested in EHRs for productivity gains, but are reluctant to share the EHRs with other players in the network. Two such dilemmas are:

#### *2.2.1. Information Asymmetry*

It is well-acknowledged that the physician-patient relationship is characterized by asymmetric information (Arrow, 1963; Blomqvist, 1991). This is because a physician who examines a patient acquires information about the patient which the latter cannot access on his/her own

(Blomqvist, 1991). Such information asymmetry results in provider-centrism where the providers are very much in control of their patients' healthcare decisions and choices, which may not always be in the patients' interest.

Though the health data of individual patients is maintained by healthcare providers in heavily invested systems, it is by all means a common property resource owned by both healthcare providers and patients and it should therefore be made accessible to both groups. However, the reality is that such health data is underutilized, if not totally unutilized, especially by patients for reasons beyond their control (Martinez et al., 2016). One basic reason is that healthcare providers who have invested in EHRs are unwilling to progress to the next level by sharing the data with their patients and other players in the network. If such information sharing is made possible as in an efficient market system, patients would really be empowered to shop around and choose a healthcare provider on their own, based on criteria such as cost-effectiveness, reliability and quality (Hill & Powell, 2009). This would go a long way in reducing provider-centrism, as well as, providers' return on EHR investments.

#### *2.2.2. Information Blocking*

Some healthcare providers may be willing to invest in EHRs if they perceive certain significant productivity gains from the investment. Furthermore, they may even take e-health to the next level by sharing their patients' health data with parties outside their institutional walls. However, they may limit such sharing to a select group of partners within the system or network 'to maintain a captive market share and reinforce market dominance' (Martinez et al., 2016, p.2). This may endanger the interoperability, and hence, the exchangeability and reusability of health data beyond the network. This results in patients' choices getting restricted to a few partners or players carefully selected by the healthcare provider in extreme self-interest. Such an outcome defeats the very purpose of e-health namely patient-centrism which means unlimited and ubiquitous access for patients to their health data.

It is against such a backdrop that this study aims to investigate the sustainability of a patient-centric e-health ecosystem with particular focus on the dilemmas of the healthcare providers without whose participation and cooperation patient-centric e-health may not be realized.

## 3. Game Theoretic View of Optimal Eco-System

A simple game theoretic analysis may help put the healthcare providers' predicament in perspective. Sharma & Bhattacharya (2013) have developed some of the classic dilemmas faced in knowledge sharing environments using game theory principles. Drawing from their work, the players in the e-health ecosystem may be considered either producers or consumers in the context of health information sharing. Health data is primarily produced by the healthcare providers and consumed in various ways by all the other players in the ecosystem namely the healthcare consumers, payers, vendors, regulators and info-mediaries. Let X denote the producers of health data, namely the healthcare providers and Y denote the consumers of health data, namely the other players in the ecosystem.

Using mathematical notations, the game can be described as the following:

s = number of strategies available to X

Three major strategies, namely:

$S_1$=non-adoption of e-health (may mean no HIT investment or HIT investment for intra-enterprise benefits)

$S_2$=adoption of e-health in a closed network

$S_3$= adoption of e-health in an open network,

can be considered to be available for the healthcare providers; therefore s = 3.
$S_x$ = strategy profile for X, expressed as $\{S_1, S_2, S_3\}$
P = payoff derived for each strategy of X
$P_x$ = payoff profile for X, expressed as $\{X_1, X_2, X_3\}$
$P_Y$ = payoff profile for Y, expressed as $\{Y_1, Y_2, Y_3\}$

Fig *1* shows the payoff graph for X and Y.

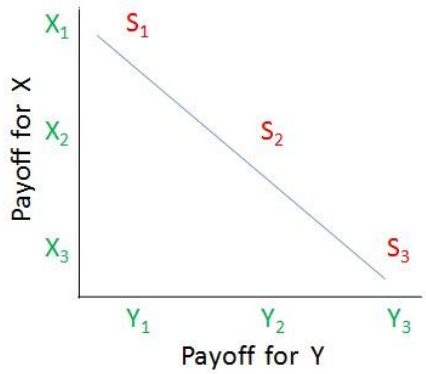


Fig 1: Payoff graph for healthcare provider strategies

The misalignment of incentives between the healthcare providers and the other players in the e-health ecosystem, a consequence of non-cooperative games, is evident from the payoff graph. The more restrictive the provider's strategy, the less the benefits for the other players. As a consequence, health providers would gravitate towards restrictive information sharing and digital access practices in order to create and capture value for themselves.

However, the innumerable benefits of e-health cannot be forgone for the reason that e-health threatens the autonomy that healthcare providers have traditionally enjoyed. Moreover, it cannot be overlooked that healthcare consumers who are the ultimate beneficiaries of e-health are also the very sources of the rich data in the possession of the healthcare providers. Hafen, Kossmann and Brand (2014) lament the fact that citizens as sources of health and other types of data, hardly have any control over such data, much less benefit from it. So it is only fair that any value in e-health be defined around healthcare consumers. How the other players create value for the healthcare consumers should be the basis upon which they should be rewarded (Porter, 2010).

Addressing the question of whether healthcare providers have the choice to shirk EHR investments: they may not have the choice if it is a mandate from the regulator. But even without a mandate from the government, providers may not have this choice in the face of rising healthcare consumerism especially in the advanced markets. Consumers are said to be gaining ground in healthcare due to Internet trends and pro-consumer health policies (Guest & Quincy, 2013). This trend is corroborated by evidence from the Singapore and the US case studies. Healthcare consumers have come to expect the qualities they value in non-healthcare settings to be present in healthcare settings as well. Cordina, Kumar and Moss (2015) argue on the strength of the findings from their study that healthcare is not any different from the other industries from a consumer's perspective - 'customer satisfaction' is a common expectation for healthcare and non-healthcare organizations alike. Therefore, to satisfy their 'customers', healthcare providers have to rise to meet their demand for ubiquitous access to their health information maintained in a longitudinal record. As Chin (2000) asserted more than a decade ago, 'the message to doctors is clear: Get Online - Do Not Be Left Behind' (p.426).

A game theoretic analysis may also be helpful to evaluate how healthcare providers might choose to respond to rising healthcare consumerism. Consider a healthcare market served by two healthcare providers A and B. Let the benchmark case be that both the healthcare providers have not adopted e-health. Adopting e-health entails costs in the form of EHR investments for the healthcare providers. Provider A serves a population size of x and has a profit that can be quantified as P. Provider B serves a population size of y and has a profit than can be quantified as Q.

A = Provider 1
B = Provider 2
x = population served by A
y = population served by B
P = A's profit in the benchmark case
Q = B's profit in the benchmark case

If A adopts e-health and B shirks e-health or if A adopts e-health ahead of B, then x and P increase while y and Q decrease. This is because of the first mover advantage that A gains to create value for its patients in the form of electronic health records. Likewise, if B adopts e-health and A shirks e-health or if B adopts e-health ahead of A, y and Q increase while x and P decrease. If both providers adopt e-health around the same time, they may be able to maintain status quo in terms of the size of the population they serve. However, their profitability will now be lower as compared to the benchmark case, due to their e-health-related investment and maintenance costs.

Therefore, it may appear that the best strategy for both the providers may be to shirk investing in e-health to preserve their original profit as in the benchmark case. However, there is more to the analysis. First, A may not be aware of B's strategy and vice versa, as is the case in non-cooperative games. If A moves first, then B loses its patients to A, and if B moves first, A loses its patients to B. Of course, loss of patients comes with loss of revenues (values) as well. Since there is an uncertainty regarding the other player's strategy, the best strategy for both players may be to play it safe by investing in e-health at least to maintain the status quo in terms of the size of the population they serve. **Error! Reference source not found.** shows the payoff matrix for the e-health adoption game.

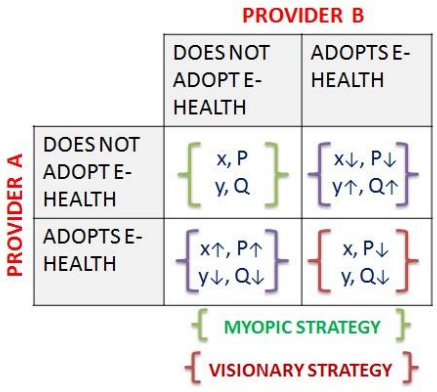


Fig 2: Payoff matrix for e-health adoption game

Even if both the providers were to jointly decide not to adopt e-health in order to preserve their current profit ('P' amount of profit for A and 'Q' amount of profit for B as in the benchmark case), there is no guarantee that their patients will remain with them. The present day healthcare consumers have better awareness of their options and therefore may tend to gravitate towards options that offer them more value. For instance, when healthcare consumers can go as far as

to undertake medical tourism to countries where the healthcare system offers better value for their money (McLean, 2007; Herzlinger, 2010), they may least hesitate to switch their loyalty to another provider in an alternate healthcare market within their community or region, who offers more value (in this context value refers to e-health). This will endanger the status quo for A and B both in terms of their profits, as well as in terms of the population sizes they serve.

Thus, in any case, the best strategy for A and B may be to adopt e-health so as to at least be equipped to offer the best value they could to their customers. Moreover embracing e-health may place them on the path to discovering new business opportunities and new markets. Both A and B shirking e-health may appear to be the best strategy but it can only be so for the short term. Therefore this course of action is referred to as a 'myopic strategy'. However both A and B investing in e-health so as not to be left behind in terms of the opportunities brought forth by e-health may be the best long term strategy, referred to as a 'visionary strategy'. So, it seems like healthcare providers may not have any other sustainable option but to invest in EHR to ensure that they are not left behind in the e-health game.

However, to encourage e-health adoption among the healthcare providers, it would help if there is a clear mandate from the government with provision for incentives. Hill and Powell (2009) insist that a national-level agenda is necessary to make digital health a reality and identify government incentives as one of the critical success factors for national-level e-health implementations. The two case studies also served to show this point. While the US case study demonstrated that incentives for EHR adoption and meaningful use work to a reasonable extent, the Singapore case study proved that without incentives the healthcare providers (especially private sector GP clinics) may not be inclined to invest in the EHR. This was further substantiated by an Accenture (2012) report which showed that Singapore lagged behind the US in terms of healthcare IT adoption as well as health information exchange both in the primary and secondary care sectors.

## 4. Summary of Key Findings

It is thus evident that government intervention is crucial for initiating and developing an integrated, citizen-centric e-health. A citizen-centric e-health ecosystem is bound to generate a huge amount of health data and should therefore be designed to support an exponential growth of such data. This can be achieved best by using cloud technology which would likely ensure economy and scalability among other benefits. The huge quantum of data in the system thus designed may then be harnessed for big data analytics which has the potential to drive productivity, innovation, competition, accountability, new values and business models in healthcare.

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