Abstract

The objective of this study is to identify the value that Health Information Exchanges (HIE) implemented in the U.S. healthcare system brings for physicians in referral processes. Mainly, we argue that a primary care physician who has adopted HIE is connected with more specialists in the referral network than another physician who has not adopted HIE. This enables her to make a better decision in a referral process with regards to selecting an appropriate specialist. Second, we argue that HIE brings a competitive advantage for specialists; a specialist who has adopted HIE becomes more popular in the referral network than other specialists. We further argue that a primary care physician who has adopted HIE tends to refer to the specialists who have also adopted HIE. This study provides an insight on the benefits of HIE to physicians in referral processes which in turn encourage more physicians to adopt it.

Keywords

Health Information Exchanges, Physicians' Referral Network, Social Network Analysis

Introduction

Health Information Exchanges (HIE) has become a main part of the U.S healthcare system since the enactment of Health Information Technology for Economic and Clinical Health Act (Vest et al. 2010). HIE enables healthcare providers to electronically access and share patients' medical information across the continuum of care. Availability of patients' medical information through HIE enhances the quality of care (Branger et al. 1994; Kaelber et al. 2007; Smith et al. 2005).

Although a substantial number of studies showed that HIE can help physicians make better decisions and reduce costs (Frisse et al. 2012; Overhage et al. 2005; Vest et al. 2015; Walker et al. 2005), healthcare providers are not encouraged enough to adopt HIE or to increase their level of HIE usage. Prior studies mainly focused on HIE benefits for insurance providers and patients (Bailey et al. 2013; Lammers et al. 2014; Yaraghi 2015), while neglecting to demonstrate the benefits of HIE for physicians. Currently, there has been a growing interest among healthcare policy makers in promoting the HIE adoption by showing its value for physicians. This study takes a step in that direction by proposing and testing a model to show the value that HIE brings for physicians in a referral network.

Physicians may decide to refer their patients to another physician, usually when a primary care physician needs a specialist to intervene for further examination. For a specific medical problem, a primary care physician usually has a choice of some specialists to whom she can refer. Despite the importance of referrals, primary care physicians usually are not aware of the full range of available specialists, and thus they cannot make efficient decisions in referral processes (Mehrotra et al. 2011).
We basically argue that physicians who are HIE members, i.e. physicians who have adopted HIE, have more centrality in the referral network. “Centrality” in the referral network indicates a physician’s level of connection to other physicians. We postulate that a primary care physician who is an HIE member is connected to more specialists compared to those who are not members. This enables her to select a more appropriate specialist for a patient in a referral process, which in turn makes the referral process more efficient. In addition, we argue that HIE brings a competitive advantage for the specialists who are HIE members; they receive more referrals compared to those who are not members. Finally, we argue that primary care physicians who are HIE members refer their patients to the specialists who are also members.

The Impact of HIE on Physicians’ Referral Patterns: Hypotheses

The HIE system is a multisided information sharing platform that connects four major sides: patients, electronic medical data providers, healthcare providers, and insurance companies (Yaraghi et al. 2014). Therefore, the HIE platform provides a kind of network through which physicians get familiar with the physicians whom they did not know before. This, in turn, provides them more available options when they need to select a specialist for a patient. Subsequently, they have the chance of creating new connections with the physicians to whom they were not connected before in the referral network.

**Hypothesis 1:** A primary care physician who is an HIE member has access to a larger number of specialists than a non-member does.

We argue that specialists who are HIE members are more popular in the referral network as they are able to provide a better care for patients. HIE enables specialists electronically to access the results of medical procedures that were performed previously for the patients (Vest et al. 2015). Accessing this information prevents the duplication of tests, redundant collection of information from the patients, wasted visits, and medication errors. As a result, a specialist who is an HIE member will be able to deliver better care than a specialist who is not a member. This gives primary care physicians a sense of assurance that their patients will be provided a quality care. Given this, the specialists who are HIE members will receive more referrals than other specialists.

**Hypothesis 2:** A specialist who is an HIE member is more likely to receive a referral than a non-member.

Many studies have demonstrated the impact of similarity on establishing professional relationships among healthcare providers (Ferlie et al. 2005; Keating et al. 2007; West et al. 2005). Correspondingly, we argue that primary care physicians who are HIE members refer their patients to the specialists who are HIE members rather than non-members. There are two main reasons behind our argument. First, we believe that HIE members refer to HIE members rather than non-members because the HIE platform improves referral processes, and benefits both physicians and patients. Second, the similarity among physicians with regard to their HIE membership establishes some bonds among them, which makes their communication easier than that with non-members. As a result, they prefer to refer their patients to each other rather than non-members.

**Hypothesis 3:** A primary care physician who is an HIE member tends to refer to a specialist who also is a member rather than non-member.

**Methodology**

To test our hypotheses, we develop a model to analyze the evolution of physicians’ referral network over time by applying the stochastic modeling tool known as Simulation Investigation for Empirical Network Analysis (SIENA) (Snijders et al. 2010). SIENA is a statistical tool designed to analyze longitudinal network data, i.e. two or more sets of observations over time, where each set is referred to as a “wave” (Ripley et al. 2011). In this section, first we briefly introduce SIENA. Next, using SIENA we develop a model to analyze the evolution of the referral network over time. Finally, we introduce our datasets.

**Introduction to SIENA**

The defining characteristic of the SIENA is that it models changes in a network from the perspective of actors. The main assumption of SIENA is that a network evolves as a stochastic process in which the decision of changes in the network is made by actors. Specifically, given two waves of a network over time,
this tool assumes that the transition from the observed network at the first point of time to the second point, is decomposed into very small steps. In each mini-step, one actor is randomly chosen, and is given the opportunity of making only one change in the network with regards to her own ties. In particular, the chosen actor can decide to create a new tie in the network, terminate one of her ties, or remain as her current state. These changes are probabilistic, and are made based on the evaluation of an objective function. The objective function represent actors’ satisfaction level with the network. In defining the objective function, a combination of configurations, which are called effects or explanatory variables, is used to specify the way in which actors decide to change. In fact, the chosen actor evaluates the objective function for all of her possible changes and she makes the change by which her objective function is maximized. Besides the objective function, the model has a rate function. The rate function models the speed by which each network actor gets an opportunity for evaluating her objective function, and perform a change (Ripley et al. 2011). The rate function is usually constant across actors, but may vary across waves. The constant rate function represents the number of times that each actor gets the opportunity to change.

**Referral Network Model**

We consider a referral structure among physicians as a network in which nodes are physicians and specialists, and ties or edges represent the referrals taking place between them. Specifically, we create a two-mode network in which the first type of nodes are primary care physicians, and the second type are specialists. We focus on the referrals taking place from the primary care physicians to the specialists, which means that the ties are unidirectional from the first type of nodes to the second type. As the ties in this network are initiated from primary care physicians, we assume that primary care physicians are actors, and the network is actor oriented in the sense that primary care physicians decide to change their ties to the specialists. The referral network is stochastic as it changes over time.

We model the dynamics of referral network using a set of effects or explanatory variables. The proposed explanatory variables are provided in Table 1. In this table, $x_{ij}$ is a binary variable, it is 1 if primary care physician $i$ refers to specialist $j$. $HIE$ is also a binary variable which is 1 for physicians who are HIE members. The main explanatory variables are Activity effect for HIE, Popularity effect for HIE, and homophily effect for HIE. The estimated parameters corresponding to these effects will be used to test H1, H2, and H3 respectively. The rest of the explanatory variables are included to control the impact of physicians’ attributes such as experience of specialists, dyadic attributes such as the similarity of physicians with regards to gender, and structural effects such as 4 cycle effect. The objective function, which is a linear combination of the explanatory variables, is presented according to the Equation 1. In this equation, $x$ represents a realized referral network, $\beta_k$, $k=\{1,…,9\}$ denotes the weight or parameter of the explanatory variable $s_{ik}(x)$. In fact, the model estimates the parameter of each explanatory variable in the objective function. Each estimated parameter represents the extent to which the corresponding effect is important in shaping the referral network over time.

$$f^\text{HIE}_{kt}(x) = \sum_{i=1}^{n} \beta_{ik} s_{ik}(x)$$  \hspace{1cm} \text{Eq.1}

**Data Sources**

We use three publicly available datasets: “Annual Physician Referral” dataset, “Physicians Compare” dataset, and “HIE Adoption” dataset. The first two datasets are provided by the Centers for Medicare and Medicaid Services (CMS), and the third one is provided by the HEALTHeLINK, regional HIE organization in Western New York. The Annual Physician Referral dataset includes the information about number of patients that are referred by each physician to another physician. This data is available for years 2009 to 2014. The Physician Compare dataset includes physician-level characteristics such as gender and specialty. Finally, HIE Adoption Data provides the information on date of HIE adoption by physicians.

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1 4-cycle effect is a common structural effect which is usually taken into consideration when modeling two-mode networks. The 4-cycle structure occurs when given that actor A has outgoing ties to C and D, and actor B also has an outgoing tie to C, then actor B creates a tie to D as well.
Results and Discussion

Table 2 shows the estimated parameters corresponding to the proposed explanatory variables in Eq. 1 by using the referral data of the consecutive years 2009-2010-2011-2012\(^2\). The model is estimated in package \texttt{Rsiena} in software R\(^3\). The significantly positive estimated parameter for Activity effect for HIE supports H1. This indicates that a primary care physician who is an HIE member refers to a larger number of specialist than a non-member does. This implies that a primary care physician who is an HIE member is aware of more available specialists to refer to than non-members. We thus argue that it is more likely that an HIE member physician selects an appropriate specialist in a referral process. The significantly positive estimated parameter for Homophily effect for HIE supports H3. This indicates that a primary care physician who is an HIE member tends to select specialists who are HIE members rather than non-members. This finding is consistent with the findings of an earlier study by Eftekhari et al. (2016).

Surprisingly, the numerical results do not support H2. We believe that this could be attributed to the impact of time. That is to say, there could be heterogeneity in Popularity effect for HIE over time. This means that Popularity effect for HIE could be stronger in the earlier period and then become weaker. This may be the reason that our results show that the estimated parameter is insignificant. For future research, we plan to investigate the impact of time on the relationship among the popularity of specialists in the referral network and HIE membership.

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(s_{11}^{x} (x) = \sum_{i} x_{ij} )</td>
<td>Density: Represents the density of the network; the tendency of primary care physicians to refer in general.</td>
</tr>
<tr>
<td>(s_{12}^{4} (x) = \sum_{ij} x_{ij} )</td>
<td>4-cycle: Represents the extent to which 4-cycle structure exists in the referral network.</td>
</tr>
<tr>
<td>(s_{1k}^{x} (x) = \sum_{ij} x_{ij} )</td>
<td>Popularity: Represent the extent to which primary care physicians tend to refer to specialists who are receiving more referrals, specialist who are more popular.</td>
</tr>
<tr>
<td>(s_{1k}^{x} (x) = \sum_{ij} x_{ij} )</td>
<td>Dyadic covariate effect for gender: Represents the extent to which primary care physicians tend to refer to specialists with the same gender.</td>
</tr>
<tr>
<td>(s_{1k}^{p} (x) = \sum_{ij} x_{ij} )</td>
<td>Dyadic covariate effect for practice: Represents the extent to which primary care physicians refer to specialists who are in their practice.</td>
</tr>
<tr>
<td>(s_{1k}^{x} (x) = \sum_{ij} x_{ij} )</td>
<td>Popularity effect for variable experience: Represent the extent to which primary care physicians refer to specialists who are more experienced.</td>
</tr>
<tr>
<td>(s_{1k}^{x} (x) = \sum_{ij} x_{ij} )</td>
<td>Activity effect for HIE: Represents the extent to which primary care physicians who are HIE members tend to refer to more specialists.</td>
</tr>
<tr>
<td>(s_{1k}^{x} (x) = \sum_{ij} x_{ij} )</td>
<td>Popularity effect for HIE: Represents the extent to which primary care physicians tend to refer to HIE members.</td>
</tr>
<tr>
<td>(s_{1k}^{x} (x) = \sum_{ij} x_{ij} )</td>
<td>Homophily effect for HIE: Represents the extent to which primary care physicians who are HIE members refer to specialist who are also members.</td>
</tr>
</tbody>
</table>

Table 1: Proposed Explanatory Variables for the Objective Function Presented in Eq.1

Conclusion and Future Work

This study sheds a light on the impact of the HIE adoption on physicians’ referral patterns, and thus shows how HIE enhances the efficiency of referrals. Our major findings are: (I) A primary care physician

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\(^2\) For modeling the referral network, a minimum amount of changes in the referral ties between two consecutive waves is required. The Jaccard index is used to measure the change between any two consecutive waves to ensure that it meets this minimum requirement. The referral network data corresponding to 2012-2013-2014 are not included in the model because the change between these waves does not meet the minimum requirement.

\(^3\) SIENA applies a simulation procedure to estimate the parameters. The model convergence ratio is 0.087 which shows the model converged adequately.
who is an HIE member tends to connect with more specialists in the referral network than non-members; (II) A primary care physician who is an HIE member tends to refer to the specialists who are also HIE members rather than non-members. In this study, we did not study the time heterogeneity of the effects. However, we plan to investigate the moderating impact of time on how HIE affects physicians’ centrality in the referral network. Our findings have significant impact on the healthcare policy making and HIE businesses. This study also contributes to an understanding of dominant factors in forming the referral network by employing a longitudinal approach. Further analysis of the dynamics of the referral network is suggested with regard to exploring physicians’ preferences in their referral decisions.

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Estimated Parameter (Standard Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>-3.109* (0.023)</td>
</tr>
<tr>
<td>4-cycle</td>
<td>0.036* (0.001)</td>
</tr>
<tr>
<td>Popularity</td>
<td>0.023* (0.002)</td>
</tr>
<tr>
<td>Dyadic covariate effect for gender</td>
<td>0.129 (0.032)</td>
</tr>
<tr>
<td>Dyadic covariate effect for practice</td>
<td>1.666* (0.059)</td>
</tr>
<tr>
<td>Popularity effect for variable experience</td>
<td>-0.008* (0.001)</td>
</tr>
<tr>
<td>Activity effect for HIE</td>
<td>0.508* (0.122)</td>
</tr>
<tr>
<td>Popularity effect for HIE</td>
<td>-0.083 (0.048)</td>
</tr>
<tr>
<td>Homophily effect for HIE</td>
<td>0.491 (0.099)</td>
</tr>
</tbody>
</table>

Table 2: Estimated Parameters for the Proposed Explanatory Variables in Eq.1 (*: p-value <0.01)

REFERENCES


