The Effect of Network Centrality of Medical Specialists on Their Performance: Evidence from an Italian Health Information Exchange Platform

Claudio Saccavini
Arsenal.IT Centro Veneto Ricerca e Innovazione per la Sanità Digitale

Giovanni Vaia
Università Ca' Foscari Venezia

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Short Paper

Cristina Trocin
Ph.D. Student
Department of Management
University Ca' Foscari of Venice, Italy
cristina.trocin@unive.it

Daria Arkhipova
Postdoctoral Research Fellow
Department of Management
University Ca' Foscari of Venice, Italy
daria.arkhipova@unive.it

Gwanhoo Lee
Professor of Information Technology and Analytics
Kogod School of Business American University, Washington DC, USA
glee@american.edu

Giovanni Vaia
Professor of Digital Management
Department of Management
University Ca' Foscari of Venice, Italy
g.vaia@unive.it

Claudio Saccavini
Chief Information Officer Consorzio Arsenal IT
Centro Veneto Ricerca e Innovazione per la Sanità Digitale, Italy
csaccavini@consorzioarsenal.it

Abstract

Health information exchanges (HIEs) are multi-sided platforms that exhibit network properties, whose value for each user resides in the information that "spills over" from the other users. Most of the studies fail to recognize that much of the institutional performance improvements due to the adoption of HIEs could be realized at the level of an actual user. Multisided platforms have the potential to decrease costs of neighboring organizations but this presumption is not clear at the service delivery unit of analysis. It does not take into account the network characteristics through which the information is exchanged. We analyze HIE system as a social network and put forward a claim that a single medical specialist can be a part of several distinct networks simultaneously. Social embeddedness approach allows us to understand the mechanisms through which economic transactions become embedded in social relations, which in turn affects the allocations of resources and of the costs. We investigate how centrality in different networks affects medical specialists' performance through facilitated information sharing in multi-sided platforms. We use OLS regression to test our hypotheses. Our unit of analysis is a single medical specialist.

Keywords: *Health information exchange (HIE), multi-sided platforms, Social network embeddedness, network centrality, information spillovers*

Introduction

Health information exchanges (HIEs) are digital platforms intended to improve efficiency and quality of healthcare delivery through integration and facilitated sharing of patient-related information among healthcare providers (Kohli and Tan, 2016). By design, such multi-sided platforms exhibit network properties in that they create a liaison between multiple users, and the amount of value that each user extracts from the platform increases as more users contribute to the platform (Yaraghi et al., 2015, 2014; Miller and Tucker, 2014). The value of HIEs for each user thus resides in the information that "spills over" from the other users (Menon and Sarkar, 2018) as it provides a more comprehensive overview of the patient health situation and, consequently, enables the user to provide proper treatment at a lower cost.

There is a continuing interest in investigating the phenomenon of HIEs in management and information systems (IS) research from the network perspective (Yaraghi et al., 2014, 2015; Uddin et al., 2011; Uddin and Hossain, 2011). Some authors evaluated the success of HIE implementation efforts in terms of platform adoption (Adjerid et al., 2018; Angst and Agarwal, 2009), diffusion (Miller and Tucker, 2009), consent for sharing personal medical data (Kuperman, 2011) at group level without investigating the tangible performance improvements following HIE adoption at individual user level across care organizations. Others have focused on HIE adoption decisions at institutional level and attributed them to factors such as network externalities (Miller and Tucker, 2009), spillover effects of IT investments within hospital networks (Atasoy et al., 2017) and network position of a focal medical practice (Yaraghi et al., 2015).

However, most of the studies focus on the initial services of HIE platforms such as electronic medical records (EMR) or Web services for downloading medical data (Yaraghi et al., 2015). Yet other authors tested analytical models on limited datasets with medical information from laboratory reports, radiology reports, and hospital transcriptions (Yaraghi et al., 2014) only in some departments such as treatment for hip replacement (Udin and Hossain, 2013) and taking into consideration only those patients with a health insurance in the post cure phase (Uddin et al., 2011). While some insights and commonalities have been identified, most of them focused on coordination cost and Social Network Analysis method for investigating the initial digital services of HIE platform. Most of the prior work fails to recognize that much of the institutional performance improvements could be realized at the level of an actual user, who enters, accesses and uses patient information on the platform for making patient-related decisions based on his/her medical history (Ayabakan et al., 2017).

The purpose of this paper is to measure the performance of medical specialist while exchanging medical information with multiple actors. In line with the prior research, we analyze HIE system as a network and put forward a claim that a single medical specialist can be a part of several distinct networks simultaneously (Yaraghi et al., 2014). The inherent nature of social relationships characterizing each of these networks may vary, and so may the position of the user within each network – and taken together, these characteristics will jointly co-determine the extent to which a user will be able to obtain performance benefits from using the HIE platform. For example, a medical specialist can benefit from exchanging patient information through the platform (1) with other medics in his geographical location, (2) with other professionals in the same area of medical specialization or (3) with her colleagues in the same medical institution. Heterogeneity in network embeddedness will then imply, for instance, that the specialist in question may enjoy a central position within his/her geographical network and at the same time have a peripheral position in the network of specialists outside her location.

We adopt social network perspective (Yaraghi et al., 2015, 2013) to examine how centrality in different networks affects medical specialists' performance through exchanged information in multi-sided platforms. More specifically, we study how positional centrality in three different networks – geographical, professional and institutional – affects performance characteristics of an individual doctor and explore how different nature of ties in each network influences the relationship between positional centrality and performance.

The remainder of the paper is organized as follows: we review the relevant prior literature, present our research model and hypotheses, and then describe our research setting and data analysis methods.

Theoretical background

Information Spillover and Healthcare Cost

Information is becoming a crucial economic asset. Combined with technology infrastructures, information has the potential to lower costs and increase the quality of the delivered services (Adjerid et al., 2018). It has an effect in organizations, markets or industry only when it is dynamic and continuously exchanged among core and peripheral actors (Leischnig et al., 2017). Information sharing impacts the performance at organizational and individual level. Actors, who use exchanged data, experience an increase in their own performance, which leads to higher efficiency also at organizational level.

User consent to sharing personal medical information on Health Information Exchange platforms is an important challenge the health IT providers face during the data collection. Recent studies (Yaraghi et al., 2015) investigated the underlying factors of patients' willingness to disclose their medical information on HIE platforms, the characteristics of the patients and the role of the physicians. Yaraghi et al. (2015) highlighted that medical staff has a primary role in this process as they have the ethical and legal responsibility to increase the public awareness about the benefits and risks of multisided platforms. They argued that the potential of HIE can be realized if the platform is used effectively by an increasing number of users through earning the trust of the patients.

Other prior studies have provided evidence that Information Technology (IT) enables organizations to improve its performance in terms of efficiency and quality of healthcare delivery thanks to multi-sided platforms that collect, create and share data (Hao et al., 2018). Health Information Exchanges may decrease the performance of those actors who enter the new data in the system, but it can increase the efficiency of other actors who use these medical data, creating spillovers from information sharing (Atassoy et al., 2017). Yaraghi et al. (2014) investigated the role of user-specific and network specific factors in the adoption, use and practices of service co-production within organizational boundaries. They developed an analytical model to capture the latent practice efficiency in coproduction of HIE services and test it on the first services available on the platform. Kuperman (2011) provided a historical path to the HITECH (Health Information Technology for Economic and Clinical Health Act). Kuperman unveiled that interoperability activities of automated health data started two decades ago by individual initiatives and created the directions for the actual health information exchange.

Spillover effects is a term used for benefits obtained by a firm from the efforts of another firm. This refers to those events and/or knowledge of one context that occur because something seemingly unrelated occurred in another context. There is a vast literature in information systems (IS) that investigated who gains more from the IT investments, whether they are captured by upstream or downstream industries (Chang et al, 2012). Information spillovers are defined as information benefits that a firm gain thanks to the digital investments of another firm (Menon and Sarkar, 2018). For instance, if an employee from one unit or organization is transferred to another division, the welcoming unit will experience benefits due to labor mobility. However, these benefits can be gained only if the organization has the access and skills to use the platform by making necessary IT investments and if the users actively share data via digital platforms.

In the context of healthcare, information spillover perspective was used to investigate the relationship between Electronic Healthcare Records (EHR) adoption and cost reduction as it was unclear whether the adoption costs of EHR were absorbed and EHR actually lowered healthcare expenditure (Atassoy et al, 2017). According to this perspective, the benefits of time, resources and effort invested in the HIE multisided platform of one physician will be experienced by the neighboring physicians or other care actors who will review the updated information. HIE has the potential to decrease costs of neighboring organizations but this presumption is not clear at the service delivery unit of analysis. The main reason refers to the fact it does not take into account the network characteristics through which the information is exchanged.

Social Embeddedness Theory and Multi-sided Platforms

According to the social embeddedness perspective (Bird and Zellweger, 2018; Elfenbein and Zenger, 2017) an individual is engaged in a complex web of social relationships and affiliated with various social groups.

An individual's performance is in part determined by the two most prominent network characteristics: (1) the centrality of her position within each social group (i.e. network embeddedness) and (2) the intensity of the relationships that she maintains with each member of her network (i.e. tie strength). Network embeddedness has been shown to facilitate knowledge transfer between the actors within the same network (Reagans and McEvily, 2003) and increase the amount of information shared between individuals (Aral and Van Alstyne, 2011). As regards the strength of the relationships ties, prior studies have demonstrated that while the presence of weak ties exposes an individual to the novel information from distant social groups (Baldassarri, 2007), individuals with strong social ties tend to share more fine-grained information and do so more frequently thanks to continuous personal interactions (Aral and Walker, 2014).

According to Bird and Zellweger (2018), a firm's growth is grounded in the social relationships of the entrepreneurs and the type of the relationship plays a central role. Therefore, the results within and across the firm's' boundaries depend on the nature of social relations and networks of relations. Thus, the structure of social networks and social relations can be an important factor for the efficiency based on exchanged information. Moreover, stable network of relations mediates complex transactions and have an impact on the costs associated with the transactions. Bird and Zellweger (2018) explain the reasons economic transactions become embedded in social relations through social embeddedness approach, which in turn affects the allocations of resources and of the costs.

Baldassarri (2007) provides a theoretical elaboration of the concept of embeddedness, which highlights the role of social relations and networks in economic behavior. Social-structural configurations are related to the efficiency of operating costs. However, the integration of social relations and networks with operating costs is an important viewpoint that requires a careful attention because they influence not only the firm's' efficiency or organizational performance but also the way complex and intermediate exchanges are carried out and priced. The concept of embeddedness captures the idea that the choices performed by individuals are refracted by social relations within which they exist. The key premise is that social and economic behavior are strictly interrelated so people should not rely only on regulations or the self-interest of the actors to understand and predict their choices but also on the effects of relationships among these actors. The social network exerts embeddedness constraints and benefits on firms' decisions and actions (Jiang et al, 2018).

This perspective explains that expectations of cooperative behavior influence the exchange of knowledge, resources and information among firms and trustful relations facilitate the resource transfer between actors involved in the network (Uzzi and Gillespie, 2002). The central proposition of this economic sociology of networks is that formal and informal ties that generate spillover benefits result in a network of firm actors. However, recent studies highlighted the risks associated with the relationships and their nature (Elfenbein and Zenger, 2017). Repeated information exchanges between actors and firms may improve efficiency, provide a continuity of service delivery, and expand the value produced during the transactions. These effects might spill over the firms' boundaries. This perspective brings also the dark side of the relationships in that the benefits of relationships today might come at the expenses of future needs better suited by other relationships.

The positive relationship between network centrality and the efficiency and quality was revealed in studies of the diffusion of innovations (Reagan and McEvily, 2003) while focusing social networks, on the status of the individuals in predicting the quality of the information they receive (Grewal et al, 2006). Following our discussion about the potential value of exchanged information in multi-sided platforms, the concept of centrality explains the extent to which an information is shared and brings benefits at individual and organizational level (Yaraghi et al, 2015). The centrality of an actor in the network may define the extension of use of HIE and may lead to increased efficiency of practices (Aral and Van Alstyne, 2011).

Research model

In this paper, we are interested in understanding whether network centrality of a medical specialist has an impact on performance and how this effect varies depending on the type of network she is embedded in. To that end, we have identified three types of networks a medical specialist can be affiliated with: (1) geographical network, (2) professional network and (3) institutional network.

Network centrality is defined in terms of the number of links (patients) shared between a focal node (medical specialist) with all other nodes in the network and is associated with the larger amounts of information channeled towards a central node through multiple links (Aral and Van Alstyne, 2011). Whereas the network position determines the amount of information accessed through the network, the strength of ties between the nodes will affect the characteristics of information that becomes accessible. To that end, weaker ties between the nodes imply that information is not confined to the closed circle of nodes in the immediate proximity of the focal node but instead emanates from more remote and distant sources (Granovetter, 1985). As a result, the nodes that are "weakly connected" with the focal node will provide less overlapping and more new information.

In the context of our study, central position in the geographical network implies that a medical specialist shares multiple patients with her colleagues in the same geographical area. Considering that this situation is observed when patients require different treatments from at least two doctors in the same location, using a platform enables each doctor involved to access more information regarding the medical history of a patient and obtain a broader picture and, as a result, improve their performance. At the same time, the information they access through HIEs is likely to be more heterogeneous and proceed from the medical specialists with diverse professional backgrounds thus providing alternative perspectives on health issues resulting in better performance. Hence, we posit:

- H1: Medical specialists with higher **geographical network centrality** will exhibit higher level of performance

Central position in the professional network implies that a medical specialist treats multiple patients followed by several other doctors in the same field (e.g. dermatology) that provides additional services. In the absence of frequent personal interactions between network actors, the theory would suggest that considering the weakness of the ties between the network actors, they should be exposed to a broader scope of new information by interacting with diverse groups (Granovetter, 1985; Uzzi, 1997). However, as the network is comprised of the actors with the same professional background, it stands to reason that their contributions on the platform will be "new" in terms of degree of specificity and depth but not in terms of breadth or coverage. In this case, a medic gets access to patient history in the system that allows him to reconstruct a series of prior treatments prescribed by preceding doctors and adjust the "new" treatment scheme based on prior outcomes thereby enhancing performance. Therefore, we posit:

- H2: Medical specialists with higher **professional network centrality** will exhibit higher level of performance

Central position in the institutional network implies that a medical specialist follows multiple patients that are observed by several other doctors within the same hospital. In this case, the effect of sharing information via platform is beneficial but is likely to be reinforced by formal and informal relational mechanisms between medical specialists working in close physical proximity with one another in the same hospital (Moran, 2005). As relationships between colleagues within the same institution represent stronger ties, information will be shared between colleagues within institutional network through social interactions more frequently and will be characterized with the greater level of detail (Aral and Walker, 2014). As a result, medical professionals in an institutional network will be able to complement information obtained through HIE with more fine-grained information about the patient through face-to-face interactions (Bapna et al., 2017) and, in doing so, they will be able to take more informed treatment decisions thereby further increasing their performance. Hence, we expect the effect of positional centrality in institutional network to be positive but of greater magnitude compared to geographical and professional networks:

- H3: Medical specialists with higher centrality in **institutional network centrality** will exhibit higher level of performance
- H4: The effect of **institutional network centrality** on performance will be **greater** than the effect of **geographical network centrality**
- H5: The effect of **institutional network centrality** on performance will be **greater** than the effect of **professional network centrality**

The graphical representation of the research model is presented in Figure 1.

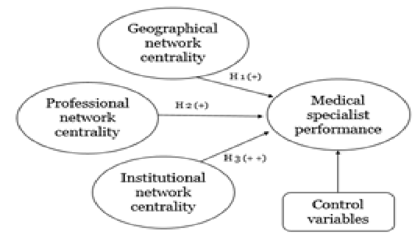

Figure 1. Conceptual Research Model

Research methodology

Research setting: Health Information Exchange in the Northeast Italian region

The research setting for this study is composed by the healthcare system in the North-Eastern Italian region. HIE project was economically, financially and politically supported by the Region and the Ministry of Economy and Finance through three action plans that were prolonged based on the achieved goals, 2012-2014, 2014-2016, 2016- till present. It represents an integration and homogenization of other previous care digital projects such as ESCAPE, DOGE. Individual initiatives were developed to solve specific needs; thus the digital systems were not technically able to communicate among each other because they were lacking a common infrastructure.

Consorzio Arsenal IT, a regional research center and innovation for digital healthcare, won the public tender to develop and implement the Health Information Exchange in all care organizations in the North-Eastern region. It is a voluntary consortium composed by 9 health care companies and 2 hospitals devoted to innovating and digitalizing the healthcare processes and organizations. Initial years were dedicated to the creation of the infrastructure of the platform to satisfy specific requirements such as a unique tool with multi-sided access points to collect, create and share medical information. Health Information Exchange platform was composed of core elements such as administrative data of the patient, references, first aid report, letters of discharge, summary health profile, pharmaceutical dossier, and consent and denial of organ and tissue donation.

Data

In this research we used a unique database provided by Consorzio Arsenal IT. The obtained data shows a comprehensive view of the HIE usage and its impacts on the population of a specific region. The data is particularly valuable because it captures the context and the specificities of each care organization, thus offering a detailed and representative perspective. The database includes patient records created in the system by care actors in the period spanning from January 2015 to April 2018 and, according to our preliminary assessment, contains over 98 mln data entries. Each record in the database corresponds to a ticket – each ticket has a unique identification number and is automatically created in the system when a patient enters in contact with a healthcare provider. The ticket remains open until the medical service is fully delivered and can undergo a series of status changes in case the involvement of several medical professionals is required for delivering a service. The instances of ticket creation, ticket status changes as well as ticket closure are time—stamped thus allowing us to reproduce the temporal sequence of all patient-related activities associated with it. For each ticket, the following data is available:

- Unique patient identification number, Patient demographic data (gender, age, residence ZIP code),
- Unique medical specialist identification number, Medical specialist location ZIP code,
- Unique identification number of a medical institution, Diagnosis code and textual description,
- ID codes of medical services provided, Costs of medical services provided

Data Analysis Methods

We use OLS regression to test our hypotheses. Our unit of analysis is a single medical specialist (also hereafter referred to as medical professional or doctor).

Dependent Variables

Our central variable of interest is performance of a medical professional. Given that prior research emphasizes the efficiency as well as the quality aspects of medical performance (Adjerid et al, 2018), we intend to use two measures of performance and examine whether the hypothesized relationships hold irrespective of the type of performance we consider.

Our first dependent variable seeks to capture the efficiency aspect of performance. Given that we analyze the data on a level of an individual medic, it appears to be problematic to use well-established measure of efficiency such as cost saving for two main reasons. First, medical organizations typically report costs at a level of a medical unit or an entire organization, and any attempt to attribute a share of costs to an individual employee will be associated with a large degree of approximation. Second, the cost of a medical professional to the public healthcare system in Italy remains largely constant over time and is not reflective of her actual performance. Provided the constraints above, we have opted for measuring efficiency in terms of time savings associated with each ticket. To that end, for each medical professional, we have calculated the average time it takes her to process a ticket based on the amount of time (in minutes) elapsed between the moment of ticket creation and the moment of ticket closure in the system. Ticket processing time is likely to be additionally influenced by the specifics of a medical service in that some services may systematically take longer time to deliver than others due to the inherent nature of diagnostic, examination and treatment procedures established in the field. To account for efficiency variability associated with service-specific factors, we normalize our dependent variable by the average time to process a ticket for the same diagnosis. Finally, given that this variable is reverse-coded, it naturally follows that the reduction in the average time to process a ticket would signify the improvement in efficiency.

Our second dependent variable addresses the quality aspect of performance. The most conventional way of measuring the quality of medical care involves collecting evaluations from patients (Provan and Sebastian, 1998)– something that is not feasible given the large number of observations in our dataset. Hence, we measure the service quality of a medical specialist as the number of "switching" patients that quit after the two visits and yet continue using the same service from a different doctor. The underlying logic behind using this measure is that patients that were unsatisfied with the service quality will switch to a different medic providing similar service, whereas satisfied patients will carry on using the services of the medic they have initially started their treatment with. We assume that it takes two visits for a patient to evaluate the quality of the medical service as a patient typically needs to schedule a second appointment to follow up. The fact that a patient proceeds with the same treatment – as reflected in the second condition included in our measure – excludes the alternative explanation that the patient stops seeing the doctor simply because he or she has recovered. This variable is reverse-coded and the reduction in the number of switching patients is interpreted as an improvement in quality.

Independent Variables

Our first independent variable is *geographical network embeddedness*. We have followed prior studies on network embeddedness in using the notion of centrality and measure this variable as the total number of patients shared between medical professionals within the same *geographical area* (Yaraghi et al., 2015; Aral and Walker, 2014; Grewal et al., 2006). To that end, we organized our dataset by ZIP code and used an adjacency matrix to calculate the total number of unique patients that a focal medic shares with all other medical professionals in the same location. To ensure comparability across areas of different sizes, the obtained measure was weighted by the number of inhabitants officially registered in each ZIP code.

Professional network embeddedness is our second explanatory variable that is operationalized as the total number of patients shared between medical professionals with the same *specialization* (e.g. dermatology, cardiology). To establish whether medics belong to the same branch of medical practice, we relied upon medical service classification code (NTR) whose first two digits correspond to a high-level definition of a medical specialization category. Next, we grouped medical specialists by their area of expertise and calculated the total number of patients that a focal medic shares with her professional network in the same branch of medicine. We then further refined our measure by weighting it by the average annual number of patient records for each specialization category.

Finally, to measure our third independent variable - *institutional network embeddedness* – we have calculated the total number of patients shared between medical professionals that are employed in the same medical *institution* (e.g. hospital, clinic). To group our observations by institution, we used the data on the institutional codes that each medical professional in our dataset is affiliated with and then proceeded with calculating the total number of patients shared by a focal medic with her colleagues working at the same organization. To account for the differences in size and relative importance of each institution, the resultant measure was weighted by the average annual number of patients treated in a given institution.

Controls

We have also included a series of control variables to account for the alternative sources of performance heterogeneity. First, performance is inevitably influenced by the experience of a medical professional. To that end, we control for tenure which is measured as the number of years a doctor has been professionally practicing medicine. Second, a medical specialist's performance can be affected by the *availability of support staff* that reduces administrative workload and strengthens focus on professional patient care. We measure this control variable as a ratio of non-medical to medical personnel in the institution / practice a focal specialist belongs to. Third, performance may be affected by the degree to which a medical professional specializes in a given area of expertise. We control for the *degree of specialization* by including a variable measuring the number of distinct service codes that a given medical specialist has registered over the 12-month period. Finally, performance can be determined by innate *personal qualities* of a medic such as attention to detail and meticulousness. To that end, we control for these characteristics by including a variable that measures an average length of textual diagnosis description entered in the system by a medic. Our assumption is that an individual that dedicates time and effort to writing a clear and well-articulated diagnosis will be less prone to entering erroneous data in the system thereby increasing performance.

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