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Procedia Social and Behavioral Sciences 10 (2011) 140–147

Procedia
Social and Behavioral Sciences

4th & 5th UK Social Networks Conference

The interplay of social interaction, individual characteristics and external influence in diffusion of innovation processes: An empirical test in medical settings

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Elsevier use only: Received date here; revised date here; accepted date here

Abstract

This paper explores mechanisms and drivers of social learning in adoption of uncertain innovations. To this purpose, we use an original dataset of about 900 hospital physicians, involved in prescribing a new drug. Then, we specify an ERG or *p** model in order to verify the tendency to exploit different formal and informal relationships with colleagues, providing information or opinions on the new product. We moreover control for the effect of alternative sources of information, i.e. marketing pressure, and antecedents of innovation, i.e. heterogeneity in individual attitude toward new products, on the probability of sending ties.

Keywords: Diffusion of innovation; social learning; medical settings; social networks; ERG or *p** models.

1. Introduction

The extant literature on diffusion of innovations greatly emphasizes the idea that social interaction among consumers can influence individual attitude and behaviour toward a new product (e.g. Arndt, 1967; Becker, 1970; Souder, 1987). In different theoretical perspectives (i.e. economic, sociological or managerial) this concept has been named as social learning (Bandura, 1971), social contagion (Marsden and Friedkin, 1993) or word of mouth (Engel et al., 1969). However, it basically refers to the same hypothesis: especially when an innovation is disruptive or its consequences uncertain, consumers tend to share their opinions or consumption experience with others. Then, mainly those less willing to take risks are likely to seek advice from others and to include it within their evaluation process of the new product or service. Let aside this general idea, the dynamics of social learning are still fairly ambiguous. Under its 'umbrella', in fact, scholars have comprised and, sometimes, confounded several mechanisms. Each one involves a different amount of knowledge transferred: peers opinion sharing (Katz and Lazarsfeld, 1955),

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doi:10.1016/j.sbspro.2011.01.017

leader-follower processes (Rogers and Schoemaker, 1971; Mak, 2008), normative pressures to conform (DiMaggio and Powell, 1983) and competitive concerns (Burt, 1987).

Controversial too are the empirical findings on the effectiveness of social learning, once contextual variables and individual attitude toward innovation have been accounted for. This mixed evidence, then, calls for a clearer definition of the hypotheses of social learning and a more careful selection of products and contexts where it can work successfully.

Following this direction, the paper looks at a specific episode, i.e. the introduction on the health care market of an uncertain innovation, namely a new drug. It, then, investigates a) which mechanisms of social interaction physicians exploit in order to acquire information or opinions on the new drug useful to decide whether to prescribe it, and b) what drives them to exert these relationships. In doing so, we neither explicitly model social learning nor test its effectiveness. This work aims at identifying when and how physicians rely on others, and then become potentially exposed to their influence.

The paper is organised as follows. Firstly we review the literature on diffusion of innovation and on rival social learning models in medical settings. Secondly, we illustrate the empirical framework and discuss the methodology, the Exponential Random Graphs or *p** models (Snijders et al., 2006) for social networks, and the dataset used to investigate structures and tendencies in relationships among physicians. Thirdly, we provide evidence of the co-existence of different social learning mechanisms, which different physicians exploit to fulfill different motivations in distinct contextual conditions. Finally, we summarise the most significant results and shortly report the main limitations to this work, together with possible developments.

2. Research design

2.1 Theoretical framework

In health care management innovativeness of practices and drugs is commonly believed fundamental to increase therapies efficacy. The widespread diffusion of innovations, nonetheless, is frequently prevented or delayed by the scarce scientific knowledge of the medical practitioners who should evaluate them, by the lack of coordination within the clinician staffs and, above all, by the uncertainty of the adoption process (West et al., 1999). Especially the introduction of a new drug is perceived as considerably risky. The highest uncertainty regards effectiveness, interactions and side effects and affects either patients or physicians. Together with other complexities of both the medical sector and, even more, the prescription process (Greenhalgh et al., 2004; Manchanda et al., 2005) - e.g. the distinction between the decision maker, i.e. the physician, and the user, i.e. the patient; the multiple levels of adoption, i.e. organizational and, then, individual; the variety of sources of external influence; the scarcity of specific information due to the restrictions, at least in EU countries (CEE 92/28), on advertising of drugs and devices; the moderate importance of price -, this combination of innovativeness and uncertainty has led a number of scholars to point out the importance of physician networks. Through interaction with colleagues, in fact, physicians acquire opinions, information and knowledge on new products or devices. And, moreover, they are likely to be influenced by others' attitude and behaviour toward them (Coleman et al., 1966; Burt, 1987; Valente, 1996).

In most studies conducted so far on diffusion of medical innovations, the issue has been addressed from an influence perspective. Thus, physicians have been generally regarded as passive adopters of new products or devices and attention has been drawn to identify the effectiveness of social learning. As a consequence, the network structure and content have not been investigated.

From this body of literature it seems just possible to identify the existence of two rival relationships through which social learning is expected to occur. According to traditional studies (Coleman et al., 1966; Burt, 1987) physicians exploit opinion sharing, advice seeking or informal discussion with peers or friends who work in the same field in order to get information and opinions on the new drug or practice. They thus exhibit a clear propensity for building strong and mutual ties, which seem to be based more on interpersonal trust and physical proximity than on knowledge asymmetry. As proven by Coleman et al. (1966) and following refinements, the influence of this relationship of opinion seeking from peers on the adoption behaviour of the new product depends on the number of ties sent. Therefore, well connected physicians receive a greater amount of information and, if they rely on others who have already adopted the new drug or practice, are more likely to adopt it. By contrast, some scholars (Tan, 2003; Nair et al., 2008) have recently shed light on the existence of a sort of very domain-specific *a priori* opinion leadership, based on reputation within the scientific community. Therefore, these authors have put forward the idea that physicians look at the opinion of their prominent colleagues and at their prescription behaviour. And, then, tend to imitate them. This relationship of opinion seeking from prominent colleagues consists of very weak and asymmetric ties. It does not imply proper interaction, since it frequently just consist of searching for their opinion or attitude toward the new product by attending meetings where these physicians give presentations, reading their papers or, in general, following their research advancements. The effectiveness of this mechanism is expected then to be more connected to the reputation of the influential than to their number.

Studies on diffusion of innovation have moreover point out that the choice to prescribe an innovative drug is influenced by other variables, in addition to social interaction with colleagues. Several scholars (Strang and Tuma, 1993; Mukherjee et al., 2002) underline the importance of marketing pressure. Others emphasize the effect of some individual characteristics, the so-called antecedents of innovation. They are absorptive capacity for new knowledge (Cohen and Levinthal, 1990) and receptivity for change (Hirschman, 1980) or innovativeness. Absorptive capacity represents the individual capability to understand, evaluate and, eventually, accept the innovation. It develops over time as learning by doing mainly from patients feedback (Coscelli and Shum, 2004). Receptivity for change measures the interest in new developments or propensity to innovate and makes a physician more or less keen to adopt the new drug.

It seems thus reasonable to put forward that the availability of alternative sources of information (i.e. the market) or the individual attitude toward the innovation (i.e. the antecedents of innovation) somehow affect the tendency to search for others' opinion and, then, to exploit social interaction.

Since this hypothesis has not be verified to date, we test it here. We moreover examine the two relationships and aim at identifying which characteristics they have and to what extent they are used.

2.2 Methodology

We examine social interaction among physicians taking place when a new drug is launched on the market. Namely, we observe which of the aforementioned relationships (opinion seeing from peers and opinion seeking from prominent colleagues) each physicians exerts in order to get information on it and, consequently, to decide whether to adopt or not.

We analyse the two relationships separately and then compared them. Applying Social Network Analysis, we represent each relationship by a binary network whose nodes are physicians and ties are opinion seeking among couples of them. The network corresponds to an adjacency matrix **X** of size $n \times n$, with n the number of nodes. The generic element of **X**, $x_{ij,}$ equals 1 if there is a tie from node i to node j (i=1, …, n; j=1, …, n; $i \neq j$) and 0 otherwise. In both the relationships we distinguish between ties sent and received. Therefore, they are represented by a directed network and the related asymmetric matrix **X**.

In order to study social learning exploitation when evaluating the new drug, we then apply Exponential Random Graph or p^* models for social networks with higher order terms (Snijders et al., 2006). In the most general form (Robins et al., 2007), an ERGM is:

$$\Pr(Y = y) = \left(\frac{1}{k}\right)\exp\left\{\sum_A \eta_A g_A(y)\right\} \tag{1}$$

where: (i) the summation is over network configurations indexed by A; (ii) η_A is the parameter corresponding to the configuration of type A; (iii) $g_A(y)=\prod_{y_{ij} \in A} y_{ij}$ is the *network statistics* corresponding to configuration A; $g_A(y)$=1 if the configuration is observed in the network **y**, and is 0 otherwise; (iv) k is a normalizing quantity included to ensure (1) is a proper probability distribution. ML estimation of the parameters via a MCMC procedure for dyadic dependence models is then performed (Snijders, 2002).

To detect the effect of innovation drivers (i.e. individual characteristics and marketing pressure) on social interaction, we focus on actor covariates (node-level effects), according to a selection model where attributes are assumed to be exogenous predictors of network ties (Robins et. al, 2001). Thus, we verify the tendency to build ties of the two types examined while controlling for our primary variables, i.e. marketing pressure and antecedents of innovation. Moreover, we check the effect of two variables which previous studies mentioned, but did not test (Van den Bulte and Lilien, 2001): prescription opportunity and perceived uncertainty. In respect to the latter, we assume that the more uncertain the context, the more expected the physician is to build social ties in order to reduce the risk.

Each individual covariate enters the model as activity effect.

Marketing pressure corresponds to detailing from pharmaceutical companies, as other forms of advertising on drugs are forbidden. It is thus captured by the number of visits each physician receives from detailing people for promoting the drug examined. *Absorptive capacity* is represented by the experience in the field (Lave and Wenger, 1991). It is captured by physician professional age, i.e. the number of years since the doctor graduated. As the experience curve tends to increase at a decreasing marginal rate, this effect enters the model as a square root function of years. Similarly to Coleman et al. (1966), *receptivity for change* is exemplified by the research orientation, which stands for the propensity to innovate. We measure it as scientific productivity, hence as the average annual number of peer reviewed publications the physician has contributed either as author or as member of the research group. The *opportunity to prescribe* is captured by a dummy on the physician hierarchical position in the hospital setting. It is well known that physicians in charge of a department or with a honorary position (coded as 1) are less likely to interact with patients and, thus, to prescribe drugs (Lilien and Van den Bulte, 2001) than others (coded as 0). Moreover, they are a less accessible source of information (Borgatti and Cross, 2003). Finally, we encompass the level of *uncertainty* each physician perceives to face in addition to the general level of risk embedded in the innovation process, which equally affects individuals. We conceive perceived uncertainty as the disease severity of patients a physician takes care of and represent it as a dummy on medical specialties. In doing so, we distinguish amongst physicians dealing with stable or unstable conditions.

Furthermore, we verify the existence of homophily between ego and alters with respect to actor covariates. We assume that the more similarity between physicians, the more equivalent level of expertise or attitude toward the new product. Therefore, the less amount of information or knowledge shared. To measure homophily we construct from actor variables some dyadic covariates. They enter the model as dyadic similarity for continuous and dyadic identity for categorical variables. These transformations are made internally in SIENA.

Finally, to capture the tendency of the network to self-organize in more complex structures than dyads, as suggested by the partial conditional dependence assumption (Pattison and Robins, 2002), we add some structural effects. We specify the degree distribution (that we measured as *alternating out-k-star*, focussing only on ties sent), the *reciprocity* effect, higher order transitivity (*alternating k-triangles*) and the preconditions for transitivity (*alternating independent two-paths*). *Alternating k-triangles* expresses transitivity as the tendency toward a comparatively high number of triangles, with an increase in probability to observe a *k-triangle* which is a decreasing function of *k*. *Alternating independent two-paths* controls for the prerequisites of triangulation, captured by the number of configurations that would be the side of *k*-triangles if there would exist a base edge.

2.3 Data

This study uses either primary or secondary data. Primary data were collected in mid 2008, a few months after a new very specific anti-pain drug had been launched on the Italian market. So as to detect how this innovation was likely to spread among hospital physicians working in the target medical area for the new product, i.e. primary healthcare, a large group of physicians potentially interested in adopting it was interviewed. Physicians were selected with a snowball sampling. We started from a sample of 200 physicians who had prescribed similar drugs and asked them to nominate colleagues according to the two relationships examined. Then, the nominated were interviewed. We stopped at wave 3, since no other physicians entered the sample. The sample were administered a questionnaire, in which they were asked to nominate peers and prominent colleagues whose opinion they look for when evaluating the new drug. Physicians were asked: ‘To decide whether to prescribe this new drug which colleagues would you go for advice or information on it?’ to capture opinion seeking from peers and ‘To decide whether to prescribe this new drug which colleagues do you consider prominent in the field and would you then follow opinions and findings on (e.g. Presentations at meetings, papers, …)?’ to capture opinion seeking from prominent colleagues. Interviews were conducted by CATI. To avoid distortions in results, the number of nominations was not fixed. The same source provided also information on the individual level of exposure to marketing pressure and on hierarchical roles.

We then integrated these data with others collected from secondary data sources: the Italian Physician Order website provided information on physicians specialties, affiliations and professional age; the National Health Ministry (NHM) dataset on disease severity and on the classification of hospital trusts, which were used in a preliminary step of analysis. The NHM distinguishes eight categories that, to our purposes, were reclassified into four groups, from more to less research oriented. They are Research Centres and Foundations, University Hospitals, Hospitals and Health Local Units, Private Organizations. At last, the number of individual contributed peer reviewed publications was obtained from Pubmed, a publicly available online datasource which information on the papers published by each physician on international peer reviewed journals during his/her career. In case of uncertain attribution, Pubmed data were matched with BiomedExperts ones.

We have data on 891 specialist physicians. They belong to 23 different specialties, although 84.90% are oncologists (34.10%) and anaesthetists (50.80%). Furthermore, interviewed physicians cover overall 380 hospital trust and well represent the real distribution over the national territory: Research Centres and Foundations account for 9.40%, University Hospitals for 16.00%, Hospitals and Health Local Units are 65.70%, Private Organizations 8.90%.

3. Results

Firstly, we computed the main network and individual descriptive statistics (Table 1). We observed that in the imitation network, once removed isolates, 53% of the initial nodes remain active. Moreover, there are no mutual dyads – i.e. the relationship is totally asymmetric – and only 37% of physicians exploit this learning mechanism. A deeper investigation into the indegree distribution point out the co-existence of a number of 'local' opinion leaders (receiving up to 10 nominations) and few 'global' ones (two physicians, whose indegree scores are 84 and 94). On the contrary, discussion with peers regards 76.4% of the specialists interviewed and is totally symmetric.
We moreover verified the high heterogeneity in the actor covariates, especially with respect to marketing pressure and receptivity for change, and their independence from one another. This suggests that they represents different effects and can be successfully used as predictors in our model. The only exception is perceived uncertainty, which correlates with either absorptive capacity or receptivity for change. However, both the correlation scores are low (-0.275 and 0.158).

Table 1: Descriptive statistics and correlations

Mean (s.e.)		Influence from the market	Absorptive capacity	Receptivity for change	Perceived uncertainty	Prescription opportunity	nOutdegree imitation	nOutdegree discussion
1.280 (2.664)	Influence from the market	1.000						
23.49 (9.896)	Absorptive capacity	-.033	1.000					
.38 (1.025)	Receptivity for change	-.013	-.038	1.000				
41.98%	Perceived uncertainty	.089**	-.275**	.158**	1.000			
1.70%	Prescription opportunity	.005	.020	.023	-.041	1.000		
.080 (.121)	nOutdegree imitation	.031	-.057	.017	.051	-.039	1.000	
.122 (.098)	nOutdegree discussion	.027	-.057	-.013	.009	.018	.160**	1.000

***p<0.01 *p<0.05. 2-tailed tests. (n=891)*

We then run the ERGM within the SIENA environment (Snjiders et al., 2007). We perform the conditional estimate, fixing the graph density. Since we deal with very peculiar networks (symmetric and asymmetric) we moreover fix *reciprocity* at a high positive value (+5) for opinion seeking from peers and at a high negative one (-5) for opinion seeking from prominent colleagues. Then we do not estimate its effect.

Table 2 displays the final model for each social learning mechanism. *Prescription opportunity* and *alternating independent two-paths* were ruled out since highly correlated with other effects. This model shows the two mechanisms differ for several characteristics and are alternatively used.

We first examined opinion seeking from peers. Focussing on activity effect, we found the propensity to build ties is explained by the positive and highly significant parameter for marketing pressure and by the negative effect of absorptive capacity. Accordingly, the greater the exposure to marketing pressure and the lower the capability to evaluate the new drug, the higher the tendency to search for others opinion. Rather intuitively, we moreover observed a high tendency toward homophily, as suggested by the estimates of similarity and identity effects, which are significant and positive for all the primary and control variables. The effects of the marketing pressure received and the level of uncertainty faced are particularly strong, thus revealing physicians choose as opinion seeking partners those peers which possess the same amount of information on the innovation and deal with similar environmental conditions. Finally, with reference to structural effects, a negative *alternating out- k-star* parameter suggests a truncated degree distribution with a tendency against particularly high degree nodes, while a positive one of *alternating k-triangle* stays for a tendency toward triangulation. The combination of the two parameters indicates the network tends to self-organize in several small groups of overlapping triangles (Robins et al. 2007: 205). Interpreted together with homophily, these findings signal a high level of homogeneity within the groups.

Then, we moved to analyse opinion seeking from prominent colleagues. The negative parameter of marketing pressure shows that the amount of communication received is expected to affect the choice to imitate prominent physicians oppositely than to share opinion with peers. To explain the propensity to copy others also contribute the negative effect of receptivity for change (i.e. the most willing to adopt innovations, the less likely to imitate) and the positive one of perceived uncertainty. The latter enters the model also as homophily, thus confirming the high domain specificity of this *a priori* opinion leaderships. In respect to the other characteristics, a clear tendency against homophily emerges. It basically proves that prominent physicians have a higher receptivity for change and receive a stronger attention from the market, which then recognises their role. At last, the network structure was modelled in a very simple manner. This relationship is explained by the positive *alternating out-k-star* parameter, which points out the network exhibits a significant discrepancy in the number of ties sent. This corresponds to a large number of physicians who do not rely on this social learning mechanism and a smaller number of others who extensively look at prominent others (from 1 up to 5 excellent colleagues) behaviour. Finally, the insignificant *alternating k-triangle* parameter reveals the absence of more complex than dyadic interactions.

Table 2: Social learning mechanisms in comparison

	Opinion seeking from peers	***Opinion seeking from prominent colleagues***
Parameter	**Estimate (s.e.)**	**Estimate (s.e.)**
Primary variables		
Marketing pressure	.0964 (.0132)*	-.0405 (.0152)*
Receptivity for change	.0676 (.0775)	-.2690 (.0550)*
Absorptive capacity	-.0150 (.0043)*	-.0053 (.0035)
Other control variables		
Perceived uncertainty	.1410 (.0814)	.2103 (.0704)*
Similarity ego/alters		
Marketing pressure	2.9775 (.3840)*	-.6387 (.2028)*
Receptivity for change	2.5706 (1.0204)*	-2.1869 (.2091)*
Absorptive capacity	1.1843 (.3503)*	.0487 (.2581)
Identity ego/alters		
Perceived uncertainty	.5167 (.0960)*	.2064 (.0837)*
Network effects		
Alternating out- k-stars	-1.1380 (.1840)*	.6885 (.0723)*
Alternating k-triangle	1.2193 (.1429)*	.6734 (.5834)

**Significant effects. (n=891)*
Standard errors in parentheses.

4. Discussion and conclusions

In this paper we examined the relational dynamics of opinion-seeking connected to the adoption of a medical innovation. We found out that the role of social learning in this context is much more complex than suggested in previous research. In detail, we highlighted that a single relationship cannot entirely capture the dynamics going on, but that physicians tend to seek information and opinions on the new drug from either peers or prominent colleagues. However, the two relationships are alternatively used. Together with the network structure, the different effect of covariates on tendency to build ties moreover implies the two types of opinion-seeking have different functions. Opinion seeking from peers is complementary to marketing pressure. It is exerted by physicians receiving a great amount of detail, who seem then be likely to look for approval of their own opinions by closing in small groups of homogeneous colleagues. Because of this homogeneity, the amount of knowledge mobilized is poor. In this relationship seems thus to be present a sort of inertia, consistently with findings of other studies that, once controlled for the effect of marketing pressure, verified its modest contribution to the adoption choice (Van den Bulte and Lilien, 2001). Taking a step further, the tendency toward triangulation is likely to indicate a collegiality in the decision-making process, which requires deeper investigation. By contrast, when not reached by marketing communication, physicians dealing with higher uncertainty and less keen to innovate, are less likely to autonomously prescribe or simply discuss with peers, and explicitly look to prominent colleagues. To diversify the risk of adapting to others' behaviour, most have multiple opinion leaders. Since these exemplar colleagues constitute their primary, when not unique, source of information, they are expected to effectively influence the individual decision-making process. Therefore, this mechanism seems more powerful and coherent with the genuine idea of social learning.

Obviously, the study has limitations. Firstly, the choice to analyse the relationships separately represents a simplification of the relational dynamics in action. In fact, it made impossible to study possible overlaps. Rather simple has also been the operationalization of some variables, above all perceived uncertainty. Since it entered the model as a dummy, and was defined as self-reported uncertainty, it could not capture the effect of slighter discrepancies among physicians perceptions of the risks faced. Collecting primary data on it, as well as more accurately modelling other covariates, like receptivity for change, could provide thus better insights into social interaction.

Finally, it seems wiser to regard this work just as a case study. Hence, the extension of conclusions from primary healthcare to other medical areas should be very cautiously attempted. Physicians employed in primary healthcare are found to be well connected also in previous studies. By contrast, evidence of the existence of a network structure of physicians in less specialized areas is poorer. Since those studies did not consider simultaneously the two relationships tested here, it could be worth replicating analyses on other areas or observing their co-evolution, also in respect to individual prescription behaviour, by means of a longitudinal model.

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