Innovation Diffusion, Social Networks and Strategic Marketing: Revisiting Medical Innovation with Agents

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1. Introduction

The classic, Medical Innovation study by Coleman, Katz and Menzel (1966) elaborates on social networks as a key component in the diffusion process. Often cited as an evidence of social contagion, Medical Innovation articulates how different patterns of interpersonal communications can influence the diffusion process at different stages of adoption. Their study identifies two broad categories of variables influencing the diffusion process. First, personal traits or individual variables, affecting individual receptivity and second, social variables influencing the adoption process as a result of social or professional ties to other members of the community. Their analyses revealed that doctors’ decisions to adopt Gammanym, the new drug, were strongly influenced by the people they are connected with, either socially or professionally, and that Gammanym often was adopted by the more connected doctors.

2. Rationale of the study

In the medical innovation study, social network data was collected by asking doctors to name three doctors they most frequently sought for discussion, friendship and advice. Three networks were derived from these questions provided a picture of social structures of the four medical communities in Illinois. However, in the original study the extent of social influence was determined for pairs of individuals. These individual networks were perceived as a set of discrete or disjointed pairs. Given the existence of multiple and overlapping networks and consequent influences on doctors’ decision making processes, analysis by pairs was the major limitation of the study. “To analyse pairs of individuals instead of single individuals may seem like only a very modest step in the direction of the analysis of networks of social relations. And so it is; it would be more satisfactory, and truer to the complexity of actual events, if it were possible to use longer chains and more ramified systems of social relations as the units of analysis. But so little developed are the methods for the analysis of social processes, that it seemed best to be content with the analysis of pair relationships”, so writes the authors themselves (Coleman, Katz and Menzel 1966, p 114). Subsequent reanalyses of data (Burt 1987, Strang 1991, Valente
1995, Marsden and Podolny 1990, Van den Bulte and Lilien 1999) failed to address this weakness. In this paper, for the first time, we reanalyse medical innovation to understand the complex interactions associated with the diffusion process. We explore the Medical Innovation findings and create a diffusion model called Gammanym, by applying Agent-based Modelling (ABM) technique. This allowed us to create a complex system, in which global phenomena emerge from the local interactions of adaptive agents (Ferber 1999). We can then show how network structures and their evolution over time determine the diffusion process.

3. Modelling Framework

Using SMALLTALK programming language, Gammanym (named after the new drug in the original study) is developed with CORMAS platform under Visual Works environment. We portray the medical community in a 8 X 8 spatial grid. The unit cell captures three different locations for professional interactions: practices, hospitals, and conference centres, randomly located over the spatial grid. Two social agents, Doctor and Laboratory, are depicted in the model. Doctors are the principal agents in the diffusion process and are initially located at their respective practices. We capture the categories of office partnership into three practice types; Private (alone in office), Centre (shared office with two partners) and Clinic (working with four colleagues). A doctor's adoption decision is influenced by a random friendship network, and a professional network created through discussions with office colleagues, or hospital visits or conference attendance. A communicating agent, Laboratory, on the other hand, influences doctors’ adoption decisions by sending information through multiple channels: medical representatives or detailman visiting practices, journals sent to doctors’ practices and commercial flyers available during conferences.

Doctors’ decisions to adopt a new drug involve interdependent local interactions among different entities in Gammanym. Based on a theory of five cognitive stages of adoption (Coleman, Katz and Menzel 1966, Rogers 1995), we specify their adoption thresholds or readiness as a step four process. Readiness is decremented when they receive an alert from different sources. At each time step, discussions with friends and colleagues, as well
as information from the lab, generates an alert. Discussions with other doctors, either friends or colleagues at practices, conferences, or hospitals generate an alert when the mean adoption rate is 0.50 or above. Doctors’ readiness is gradually reduced with alerts from all the aforementioned sources. When the readiness reaches zero, doctors adopt the new drug.

4. Simulation Results

Depending on three sets of initial conditions, cumulative diffusion curves, representing the total number of adopted doctors at each time step are markedly different (Figure 1). As several random functions are included in the algorithm, each scenario is repeated for 100 times in order to estimate output’s variability. The three scenarios are specified to evaluate the degree of influences by different factors in the diffusion process: i. *Baseline Scenario* with one innovator (seed), one detailman and one journal; ii. *Heavy Media Scenario* with different degrees of external influence, by varying the number of detailman (5) and number of journals (4); and iii. *Integration Scenario* without any external influence. Baseline scenario with one innovator and one detailman generated a logistic or S-shaped curve, similar to the ones for mixed influence diffusion models (Ryan and Gross 1943, Valente 1993). With one innovator in the system, diffusion seeds through the system as the doctors’ adoption decisions are influenced by their exposure to the new drug through media as well as interpersonal communication simultaneously. After initial phase of slow diffusion until the first inflection point at the 24 time step, the rate of adoption speeds up as more doctors are exposed to someone who has already adopted. The slope of the adoption curve changes direction when more than half of the population has adopted the new drug and gradually begins to level off as fewer doctors remain in the population who are yet to adopt. The steeper diffusion curve (Figure 1: Series 2) represents heavy media scenario, where 50% of the population adopted the new drug at the end of 12 weeks. The rate of diffusion increases up to 16 time steps and decreases afterwards as only 18% of doctors remain unaffected. At 25 time steps the curve levels off as all the doctors have adopted the new drug. Internal influence diffusion, depicted in integration scenario, represents an extremely slow diffusion process (Figure 1: Series 3).
As the only means to have an alert is to get in touch with the innovator, only 18\% of the population adopt the new innovation at the end of 68 time steps.

*How and to what extent, network structure influences the diffusion process?* We sought the answer of the fundamental query to have a better understanding of complexity generated in the diffusion process. Network variables, like clustering coefficient, degree distribution and average shortest path length indicates that social networks depicted. In Gammanym are random graphs. The analysis of network topology reveals that initially the system consisted of a number of disconnected components and quickly saturates after 7-10 time steps to form a giant clusters. Analysis on evolution of uptake suggests that under heavy media scenario the average size of clusters with agents who have adopted rise much faster than those of the other two scenario (Figure 2). Gammanym, therefore shows that though media do not influence the network structure, the speed of diffusion is largely determined by the extent of media influence.

4. Work in progress

Our result gave strong support to the importance of social networks in the diffusion process, but also show that external influence play an important role in speeding up the diffusion. In the original study doctors acknowledge the importance of commercial influences. 57\% of the 141 doctors asked to reconstruct their stages of adoption, identified detailman as the first source of information (Coleman, Katz and Menzel 1966). Van den Bulte and Lilien (1999) study provides evidences for dominant external influence by using advertisement data in addition to original data set. The authors, however, were constrained with missing data. Given the need for the rigorous analysis on the impact of external influence on the diffusion process, we are working on the extension of the Gammanym model. The extended model will elaborate on the objectives of the laboratory or pharmaceuticals and the impacts of their marketing strategies on the diffusion process. The findings will enable us: i. to formulate the optimal marketing strategies for the pharmaceutical companies. ii. to evaluate the incentive mechanism in the system of knowledge creation
We plan to look at the role of pharmaceutical companies by applying a game theoretic approach with the strategic interaction between two competing firms. Currently we are reviewing the literature to construct cost function for a representative pharmaceutical company, based on which pay off functions will be conceptualised.

*Key words:* medical innovation, diffusion, social networks, agent-based modelling, network theory, game theory
Fig. 1: Cumulative Diffusion Curves for three scenarios: Baseline (Series 1), Heavy Media (Series 2) and Integration (Series 3)
Fig. 2. Uptake clusters for three scenarios A. Number of clusters within the system; B. Maximum cluster size; C. Minimum cluster size; D. Average cluster size; and E. Standard deviation of cluster size.