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Modeling the spatio-temporal diffusion of health technology: the case of MRI in Spain

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Abstract

OBJECTIVE: To develop and test a mathematical model describing the dynamic of early stages of technology diffusion processes by considering spatial propagation on geographical domains with different local growth characteristics. This tool would be useful for health technology management applications such as forecasting the adoption of new techniques, analysis of influential factors, and the evaluation of policy measures.

METHODS: The diffusion process is described by counting the number of units observed in the system at each interval of time along the life-cycle period, i.e., the number of marketed Magnetic Resonance Imaging (MRI) units in a country. The model was built following the classical approach of using differential equations obtained from the incremental functions describing the underlying double growth process resulting from the spatial propagation to new adopting sites and the local growth processes, obtaining: dnj(t)/dt = Phi j[nj(t)]: dN(t)/dt = Delta [N(t)] + Phi [I(t)]: dI(t)/dt = Phi[I(t)]. I(t) [number of growth sites at time t], and nj(t) [number of units at site i at time t] are S-shaped functions, governed by Phi [spatial diffusion law] and Phi i [local growth law in site i]. The general analytical solution is quite complex even for relatively simple Phi i and Phi functions. However, when the study is limited to the early stages of the process, we obtain the simplified solution: N = (Pe Pt - ke kt)/(P-k): I = e kt. The model was tested by studying the emergent phase of MRI diffusion in Spain, from 1983 (the first installation) to 1992. Data were collected counting the number of units installed per location (sub-domains) in each year. The cumulative number of units at the end of 1992 was 132, geographically distributed over 45 city areas. Statistical analyses were performed with the aid of the STATGRAPHICS program.

RESULTS: Nonlinear regression analysis using the Marquardt method (Rsq = 96.68%) indicates that the number N of MRI units installed in Spain between 1983 and 1992 is properly modeled by: N = 3.53 e. 46t - 2.53e.33t. The spatial diffusion process fits well the equation I = e.46t[SE = .028 and Rsq = 97.16%].

CONCLUSIONS: A new mathematical model, expressed by differential equations and describing dynamic technology diffusion processes, has been built considering spatial propagation on geographical domains with different local growth characteristics. The differential equations have geographical domains with different local growth characteristics. The differential equations have been solved for the early stages, which is the case of emerging technologies. The model's performance has been tested using data on the diffusion of MRI devices in Spain. It has been shown to be useful to: 1) assess differences between public and private investment pattern behaviors; 2) forecast diffusion processes; and 3) study factors influencing medical technology diffusion in different regional and local situations.

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