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Market potential dynamics in innovation diffusion: Modelling the synergy between two driving forces

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ABSTRACT

The presence of a slowdown in new product life cycles has recently received notable attention from many innovation diffusion scholars, who have tried to explain and model it on a dual-market hypothesis (early market-main market). In this paper we propose an alternative explanation for the slowdown pattern, a dual-effect hypothesis, based on a recent co-evolutionary model, where diffusion results from the synergy between two driving forces: communication and adoption. An analysis of the synergistic interaction between communication and adoption, based on the likelihood ratio order or on a weak stochastic order, can inform us of which of the two had a driving role in early diffusion. We test the model on the sales data of two pharmaceutical drugs presenting a slowdown in their life cycle and observe that this is identified almost perfectly by the model in both cases. Contrary to the general expectation, according to which communication should precede adoption, our findings show that adoptions may be the main driver in early life cycle; this may be related to the drug's specific nature.

1. Introduction

The literature on innovation diffusion and new product life cycle has highlighted that in many situations the diffusion process is not as smooth as one would expect, but rather presents a perturbed pattern. In particular, it has been observed that the growth phase of the process is often characterised by the presence of a *slowdown*. The slowdown phenomenon – also known, with minor differences, as chasm, saddle or dip – indicates the situation in which, after a rapid takeoff, a product's sales reach an initial peak followed by a decline – whose length and depth may vary – and eventually by a resumption that may exceed the initial peak. While in the past there was no consensus on the concrete existence of such a phenomenon, a recent and increasing stream of literature has empirically verified that this regularity occurs in many product categories. However, the slowdown phenomenon is still posing challenges to innovation diffusion scholars, since it has been neither explained nor modelled in a unique way.

Some lines of research have followed the idea that the market for new products needs to be divided into two major segments, usually termed "visionaries and pragmatists" (see [1]), "early market and main market" (see [2], [3], [4], [5]), "influentials and imitators" (see [6]).

In particular Moore, building on the well-known categorisation of adopters proposed by [7], suggested that the market for innovations is initially represented just by early adopters and that the main market develops in a second stage of diffusion. Early and main markets are different in their attitudes and expectations towards novelties, and this difference may result in a precise separation between the two, implying a different treatment in terms of marketing strategies (see [8]). Such a separation has been theorized as a possible explanation for the slowdown pattern. Grounding on Moore's intuition, Goldenberg et al. (see [2]) have suggested that the existence of a saddle may be seen as a dual-market symptom. Their analysis has been based, first, on two exploratory studies on

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artificial markets realized with Cellular Automata models in order to verify the frequency of the saddle phenomenon in simulated situations, and then on an aggregate model to tie the dual-market explanation to saddle phenomena emerging in real situations.

In the spirit of the work by [2], Muller and Yogev (see [3]) have developed a dual-market diffusion model, in which the dynamics of the early market are expressed in Eq. (1),

$$\frac{dI(t)}{dt} = \left(p_i + q_i \frac{I(t)}{N_i}\right)(N_i - I(t)). \tag{1}$$

As one may observe the early market's cumulative adoptions, $I(t)$, are described through a simple Bass model, (BM) [9], where parameters p_i and q_i have the usual meaning and N_i is the market potential of the early market. Instead, cumulative adoptions of the main market, $M(t)$, present a more complex structure,

$$\frac{dM(t)}{dt} = \left(p_m + q_m \frac{M(t)}{N_i + N_m} + q_{im} \frac{I(t)}{N_i + N_m}\right)(N_m - M(t)). \tag{2}$$

Eq. (2) proposes a bipartition of the word-of-mouth effect, which would be partly due to communication among the main market's individuals, q_m, and partly to cross-market communications between the early and the main markets, q_{im}.

Karmeshu and Goswami (see [4]) have introduced a different methodology in order to take into account the heterogeneity of agents in a standard *normalised* Bass model, (BM),

$$\frac{dX(t)}{dt} = \alpha(1-X) + \beta X(1-X), \quad X(0) = X_0 \tag{3}$$

by modifying its basic structure via a general assumption about the stochastic nature of α and β parameters. The solution process corresponding to model (3) is the usual one based conditionally on α, β, and X_0. The authors study particular moments in the previous process describing a general joint mixing distribution $\phi(\alpha,\beta)$ by means of so-called 'two-point-distribution' (TPD) formalism. This allows for an approximate representation through six parameters, μ_i, σ_i, ν_i, $(i = \alpha,\beta)$, i.e., local means, standard deviations, and skewness. This is an innovative approach which allows a formal definition of the dynamic mean value $\mathcal{M}(t)$ of the cumulative adoption process as a linear combination of four Bass standard cumulative distributions. Studying the variation of $\frac{d\mathcal{M}(t)}{dt}$ with reference to time t for various choices of parameters, it is possible to describe unimodal and bimodal life cycles where the latter is obtained for increasing values of standard deviations σ_α and σ_β. This decomposition allows a flexible description of diffusion evolution, but not a clear and interpretable origin of the components dominating over time.

Following a different path, Van den Bulte and Joshi (see [6]) have recently dealt with the existence of a dual market and the slowdown in diffusion. The authors have developed a two-segment mixture model to account for the presence of two distinct subpopulations, namely influentials and imitators, whose adoption behaviour is captured by the following hazard functions,

$$h_1(t) = p_1 + q_1 F_1(t), \tag{4}$$

$$h_2(t) = p_2 + q_2[wF_1(t) + (1-w)F_2(t)]. \tag{5}$$

Consistently with the influentials–imitators hypothesis, Eqs. (4) and (5) show an asymmetry; in fact, type 1 may influence type 2, but the reverse cannot occur. The overall adoption process is the weighted sum of the adoption of the two segments, under the assumption that these may not have the same importance, i.e.,

$$F_m(t) = \vartheta F_1(t) + (1-\vartheta)F_2(t), \tag{6}$$

where $F_1(t)$ and $F_2(t)$ are probability distribution functions. Similarly, the weighted sum of the corresponding densities yields

$$f_m(t) = \vartheta f_1(t) + (1-\vartheta)f_2(t). \tag{7}$$

The so-called Asymmetric Influence Model (AIM) by Van den Bulte and Joshi is defined by calculating closed-form solutions of $F_1(t)$ and $F_2(t)$. The solution of $F_1(t)$ is that of the standard Bass model, while $F_2(t)$ presents a much more complex structure, referable to a Riccati equation. Though we do not report the details of such a solution, the impressive mathematical effort of the overall construction is noteworthy indeed. Abandoning the closed-form solution of F_2, the authors have proposed a numerical solution for Eq. (8),

$$\frac{dX(t)}{dt} = M[\vartheta f_1(t) + (1-\vartheta)f_2(t)] + \varepsilon(t). \tag{8}$$

Van den Bulte and Joshi's model definitely proposes a mixture of two sub-populations of adopters as a possible explanation for the chasm (or dip) exhibited by several diffusion processes: specifically such a pattern appears when considering Eq. (7), i.e., the weighted sum of two densities.