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# Technological change in the U.S. music industry: Within-product, cross-product and churn effects between competing blockbusters

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ABSTRACT

In this paper, we develop a new innovation diffusion model for two competing products, which allows us to evaluate the effect of competition both on the dynamics of within-product and cross-product word-of-mouth and on the definition of the residual market potential of each product. This model, which we call Lotka–Volterra model with churn, LVch, generalizes another model for competition, the unbalanced competition and regime change diachronic model (UCRCD), which assumes a common residual market and a delayed entrance for the second product. We compare the performance of these models in describing the competition between two blockbuster formats in the music industry, the compact cassette and the compact disc. In particular, we analyze the evolution of these technologies in the U.S. market for pre-recorded music, for which annual sales data are available from 1973 to 2012, and find that the LVch model outperforms the UCRCD. An interesting aspect of this application relies on the fact that there is a single product, the *music album*, which is commercialized in two different formats, so that competition arises between formats and not between two products in the same commercial category.



## 1. Introduction

The evolutionary theory of technological change has always stimulated great interest among researchers seeking to understand and predict how innovations arise and grow, under what circumstances they are adopted, and what the consequences of their diffusion into social and economic systems are. The historical trajectory, designed by an innovation that spreads within a system, usually follows a nonlinear path, which may be estimated with nonlinear growth models, such as the logistic (Verhulst, 1838), the Gompertz (Gompertz, 1825), or the Bass model (Bass, 1969), that emphasize the role of a special interpersonal communication channel: word-of-mouth (WOM). Typical polynomial ARIMA structures generally prove unfit for this kind of time series, characterized by non-stationarities during introductory phases that determine chilling effects and the final saturating behavior. The Bass model (BM), in particular, has been widely used to forecast the diffusion of many new products or technologies. Several other models proposed in the literature originate from it; see, for instance Meade and Islam (2006) and Peres et al. (2010). A very important extension of the BM is the Generalized Bass model (GBM) (Bass et al., 1994), which, by means of a general intervention function $x(t)$, is able to identify the effect of external perturbations modifying the shape and the speed of the process. Such perturbations may be imputed to several factors, such as marketing mix actions, regulatory interventions or environmental effects. In this respect, the GBM appears to be a very flexible tool for the description of univariate processes. Innovation diffusion, as a univariate process, has been the focus of many studies aimed at exploring the effect of factors that may facilitate growth (communication, social interactions, heterogeneity of agents, advertising, and pricing) or hinder it (network externalities or constrained supply). Clearly, the

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major limitation of such models is the fact that they shape the life cycle without considering that almost every product acts in a competitive environment, where one or more substitutes enter the market at different times and target the same set of potential adopters or on partially overlapping classes of them. In fact, substitute products may act both as barriers and as stimuli for growth, and this effect should be accounted for and measured as much as possible. A part of the current literature on competition among different products is based essentially on two marketing mix instruments: advertising and pricing policies. The Vidale–Wolfe and Lancaster combat models define a common framework for this approach (Little, 1979; Sorger, 1989; Chintagunta and Vilcassim, 1992; Erickson, 1992, 2009a,b; Chintagunta and Jain, 1995; Bass et al., 2005a,b; Naik et al., 2008; Medhin and Wan, 2009). Optimal advertising or pricing policies rest on Nash equilibria under open or closed-loop interventions. This approach assumes that the adoption process strongly depends upon advertising and pricing modulation: that is, exclusively on firm strategies. In this context, the determination of the time of release of a new product might be easier to perform. However, the role of clients or agents may be determinant in controlling WOM effects and related adoption processes in competitive markets. The literature in this area is very wide and relevant.

A special case of competition, pure substitution, is occurring between successive generations of the same product or technology, such as the series of mobile telephones and personal computers, where the migration is only possible in one direction: from the older to the newer product. Considering this situation, Norton and Bass (1987) developed a diffusion model extending the basic BM to a multiple-generation context, where later solutions may attract potential adopters of earlier ones. The Norton and Bass approach does not represent competition as a differential game between opposite technologies or alternative products but assumes a direct, explicit decay of the first entrant's sales proportionally eroded by the late entrant through a local Bass model solution. In other terms, according to this viewpoint the latest generation captures a portion of its predecessors' residual market, while older generations in no way can benefit from the presence of a new entrant. Moreover, the latest generation reaches and keeps a stationary behavior of sales over time if there is no further competitor and this stationary level is the sum of the ideal stationary level of each generation. In this sense, the Norton and Bass approach gives a partial representation of a competitive environment, which lacks more complex interactions among players in terms of residual market definition and WOM effects. A more sound differential description of competing brands or products dates back to Peterson and Mahajan (1978), where residual markets are usually product-specific and 'enhancing' components are introduced to express within-product or cross-product WOM effects, especially with reference to 'complementary' products. The literature in this area has usually considered opposite situations: the residual market as product-specific or, vice versa, as a common category resource without barriers (Mahajan et al., 1993; Kalish et al., 1995; Parker and Gatignon, 1994; Yan and Ma, 2011).

Competitors may enter the market at the same time so that their life cycles are essentially simultaneous, or, more generally, a product starts as a monopolist and gains concurrent brands along the way. Although more common in reality, the situation of sequential market entry, also called *diachronic competition*, has received quite limited attention in the literature. Among the papers dealing with the issue, we recall Krishnan et al. (2000), Savin and Terwiesh (2005), Guseo and Mortarino (2010), Guseo and Mortarino (2012), and Guseo and Mortarino (2013), where competition is modeled as a duopoly after a monopolistic period for the first entrant. In particular, the models proposed in Guseo and Mortarino (2012) and Guseo and Mortarino (2014) consider different entry times and changes in first-product parameters due to competition. The models in Guseo and Mortarino (2014), namely standard UCRCD and unrestricted UCRCD, differ from that in Guseo and Mortarino (2012) in allowing a more general structure of WOM effect where the authors assume that the two products share the same WOM since they are so similar as to be perceived as equal by consumers. In Guseo and Mortarino (2014), this assumption is relaxed, and each product is influenced by *within-product* and *cross-product word-of-mouth* effects. Standard UCRCD exhibits a bivariate closed-form solution that is nonlinear in the parameters. Its application may exploit stacked inference based on nonlinear least squares (NLS) as a function of time. Unrestricted UCRCD depicts a more general situation with free WOM components, but the corresponding differential system does not have closed-form solutions. Inference, in this case, may be organized by stacking the equations that are not explicitly time-dependent.

Previous UCRCD models do not introduce a flexible representation of the residual market as perceived by each competitor but assume a common target, which allows a totally free competition. A quite different approach in constructing a more realistic residual market, partially product-specific, may adopt a Lotka–Volterra framework, LV for short (Abramson and Zanette, 1998; Morris and Pratt, 2003; Tang and Zhang, 2005; Baláž and Williams, 2012, among others). By extending Morris and Pratt's (2003) approach, where each product has its own WOM that does not depend on competition, we propose here a Lotka–Volterra framework that includes innovative within- and cross-product effects and an independent modulation of the residual market of each competitor, taking into account 'churn' effects. The proposed Lotka–Volterra with churn model, LVch, generalizes both UCRCD models and allows us to test the relevance of parsimonious representations of competition dynamics in a duopoly in a diachronic context.

In this paper, we employ both UCRCD and LVch models, to describe not a homogeneous product category but rather to study simultaneously the life cycle of two competing blockbusters in the music industry: the compact cassette and the compact disc. In particular, we analyze the evolution of these technologies in the U.S. market for pre-recorded music, for which annual sales data are available from 1973 to 2012. An interesting aspect of this application relies on the fact that there is a single product, the *music album*, which is commercialized in two different formats, so that competition arises between formats and not between two products in the same category. Given some advancements implied by the newer format, the transition from cassettes to CDs might be interpreted as a successive generation example. However, unlike other cases of successive generations of products (e.g. computers, cellular phones), the replacement of cassettes was not obvious in early stages, when a music album released on CD was more expensive than the corresponding one on cassette, and it may have appeared to be a status symbol for a few persons requiring