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Dynamic estimation of markets exhibiting a prey–predator behavior

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ABSTRACT

The evolution of market concentration in high technology saturated markets with a dominant player is dynamically estimated, based on concepts of population biology. The mathematical description was performed using the Lotka–Volterra model and the corresponding parameters were estimated by genetic algorithms. The proposed methodology shows itself capable of estimating market equilibrium and market concentration, the latter expressed by corresponding market shares. Evaluation of the presented methodology in the area of fixed lines telecommunications market led to accurate results, as compared to historical data, in a specific case study. This methodology can provide valuable inputs for managerial decisions, strategic planning and regulatory decisions to the players of a high technology market.

1. Introduction

Telecommunications are related with the biggest and most significant civil investment regarding new technologies and services. For a long period of time they used to operate under governmental provision and monopolistic regime, mainly because of governmental strategic perceptions and military security. During this time, the telecommunications industry was a relatively stable environment (van Kranenburg & Hagedoorn, 2008), since incumbent telecommunications operators offered only traditional voice and data transfer services via fixed telecommunications networks.

The liberalization of basic fixed telephone services started during the mid-1990s. By 1999, competition for such services had become relatively common, although it was still not the policy of a majority of countries. During 1999 more than 40% of the countries in Europe and 35% of the countries in the Americas permitted competition for basic fixed services (Banerjee & Ros, 2004). However, only 22% of Asian, 15% of the Middle East, and 15% of African countries had followed. In 2000, competition for basic fixed services was still restricted in 105 countries. As far as Europe is concerned, since the 1990s the European Union (EU), in the context of its plans for a Single European Market, has been pursuing a common telecommunications regulatory policy aiming to establish a liberalized and harmonized pan-European telecommunications market, to stimulate economic growth, increase employment and the standard of living in the European Community. Towards this direction, the Commission of the European Community in the Green Paper (European Commission, 1987) has put forward the principles for the liberalization of the telecommunications sector and described the common policy, in view of the single market. The main goal of market opening and restructuring was to promote market structures that would enable the exploitation of substantial demand and innovation potentials in the communications industry. The initial regulation aimed to transform telecommunication monopolies into competitive industries. Since the 1st of January 1998 almost all of the telecommunication markets in the EU have been fully liberalized, although full liberalization was delayed in Portugal and Greece until 2000 and 2001, respectively (Grzybowski, 2008). As stated in (van Kranenburg & Hagedoorn, 2008), where an informative review regarding the European telecommunications industry can be found, "*The liberalization of European telecommunications markets and the privatization of many historically state-owned telecommunications companies are probably the two most significant changes in the landscape*".

Obviously, these changes amount to a substantially new worldwide environment for market players in the telecommunications area and present new challenges in terms of both new opportunities and new competitors. According to the contemporary economic theory regarding competition, (Baye, 2006; Shy, 1995) downward pressure on the prices of telecommunication services is likely to lead service providers to introduce new pricing packages in order to better satisfy consumer preferences. This was exactly the case when liberalization started in the new converged telecommunication market, as a fierce competition emerged between the incumbent operators and the new companies that appeared, all trying to increase the number of their customers by providing services and products in very attractive prices. This is regarded as a significant dimension of the market structure, since it plays an important part in determining market power and therefore business behavior and performance in a market that was

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reformed from a monopolistic to oligopolistic or even to a more competitive structure.

Studying the concentration of the new market schema is therefore necessary, in order to identify its possible peculiarities, to describe competitors' behavior and to provide necessary inputs to legislation and regulation authorities, regarding market structure and the degree of competition (Curry & George, 1983; Marfels, 1972; Saving, Feb., 1970; Tirole, 1988), as well as predictions for the future regarding, among others, potential entry of new providers (Baye, 2006; Shy, 1995). Moreover, market concentration, as expressed by the values of market shares, is of major interest for providers as well, since it is strongly related to managerial decisions, available actions to be taken and expectations towards competition. Such decisions are usually accompanied by investments and business plans, targeting to enhance the ability of providers to meet the market's demand. Since market shares reflect, among others, the influence of providers' pricing policies over the subscribers, this is another important aspect to be taken under consideration.

In the context of the present work, the evolution of fixed telephony market (PSTN) concentration is studied, based on the evolution of the corresponding market shares of both the incumbent and the alternative providers, by adopting approaches from evolutionary theory of population biology and population dynamics. More specifically, market evolution is estimated and forecasted by applying the Lotka–Volterra model that describes the interaction of species in a prey–predator mode (Murray, 2002; Neal, 2004). Lotka–Volterra models have already been used in literature in order to model market dynamics, mainly in a duopolistic market (Kim, Lee, & Ahn, 2006; Lopez & Sanjuan, 2001; Tschirhart, 2000; Wijeratne, Yi, & Wei, 2007), or to provide forecasts for the stock market (Lee, Lee, & Oh, 2005; Modis, 1999).

1.1. Research objectives and contribution

The above approaches, although they constitute important contributions to the literature, they refer to markets where competition is already established. The main objective of the present work is to fill this gap by proposing a methodology that can describe the dynamics of an already saturated monopolistic market, which makes its first steps towards competition. Such an analysis is expected to provide valuable information to the existing competitors, as well as to the potential entrants and regulators, regarding market structure, degree of competition and market equilibrium.

The second objective is to point out the relation of pricing schemes with the corresponding market shares. Indeed, the call charges paid by the consumers influence, up to a certain point, their decision to switch to another provider, or to stay with their present one, thus influencing the share of each competitor into the market of reference.

The third objective is the application of the proposed methodology over a number of historical data series, in order to evaluate its performance and its ability to provide accurate estimations and reliable forecasts. Therefore, the evaluation of the proposed methodology was performed over historical data regarding market shares between the incumbent operator and the alternatives, for local, national long distance and international calls in five European countries. The data used for this evaluation were extracted from Eurostat's database (http://ec.europa.eu/eurostat/).

Accomplishment of the work's objectives would provide significant contribution to both research and practice. Research would benefit by the provision of new directions towards the development of a framework that incorporates the theories of population dynamics in order to analyze and study market competition, especially for high technology markets. For practitioners, the research findings can be very useful to strategic planning and decision making, in a continuously increased competitive environment, since more accurate a-priori estimates of the market dynamics patterns can be derived, including market equilibria and the estimation of the level of customers' switching among providers.

1.2. Population dynamics

Population dynamics is the study of marginal and long-term changes in the numbers (Neal, 2004), individual weights and age composition of individuals in one or several populations, and biological and environmental processes influencing those changes. The corresponding population modeling is an application of statistical models to the study of these changes in populations as a consequence of interactions of organisms with the physical environment, with individuals of their own species (intraspecies competition), and with organisms of other species (interspecies competition). Finally, one of the most important questions population modeling seeks to answer is if interacting species can coexist or not and what are the major factors that affect coexistence.

The rest of the paper is structured as follows: Section 2 is devoted in modeling of the fixed lines market dynamics according to the population biology approach. Section 3 provides a short overview of the mathematical concepts of population dynamics, especially the dynamics of the prey–predator system. Based on these concepts, the development of the proposed methodology is presented in Section 4, and the corresponding case study results are presented in Section 5. In Section 6 the methodology's forecasting ability is evaluated and finally, Section 7 describes an overview and the conclusions of the work conducted in this paper, together with directions for future work.

2. Approaching fixed line market dynamics by population biology modeling

The hypothesis concerning the variation of population is that the rate of its change is proportional to the current size of the population and the most common approach for modeling population growth of a species, in the absence of any competitors is given by (Boyce & DiPrima, 2005; Neal, 2004)

$$\frac{dN(t)}{dt} = rN(t)\left(1 - \frac{N(t)}{K}\right) \tag{1}$$

In Eq. (1) $N(t)$ is the size of population at time t, the constant r is the growth rate, and K is the saturation level or the environmental carrying capacity, for the given species. K is the upper bound that is reached, but not exceeded, by growing populations starting below this value. Models based on the above approach are widely used in modern literature for demand estimation and forecasting, such as the logistic family growth models (Bewley & Fiebig, 1988; Fisher & Pry, 1971) and the Gompertz model (Gompertz, 1825; Rai, 1999). An application of these demand models over mobile telephony diffusion set can be found in (Michalakelis, Varoutas, & Sphicopoulos, 2008).

However, when more than one species coexist in the same environment, they are expected to interact between each other in a number of ways. Definitions and descriptions of species interaction can be found in (Begon, Townsend, & Harper, 2006, 4th ed.; Neal, 2004) and a more precise definition, regarding interaction of species, is given in (Murray, 2002), where three types of interaction are identified: (i) If the growth rate of one population is decreased and the other increased the populations are in a "*prey–predator*" situation. (ii) If the growth rate of each population is decreased then it is "*competition*". (iii) If each population's growth rate is enhanced then it is called "*mutualism*" or "*symbiosis*".

Towards this direction, the present work is based on the rationale of viewing the incumbent and the alternative operators as