



# Competitive dynamics in the operating systems market: Modeling and policy implications

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## ABSTRACT

Based on concepts of population dynamics and organizational ecology, the study analyzes the evolutionary and competitive dynamics of the highly concentrated desktop/laptop operating systems market and draws conclusions on the impact of open source software on market competition. Market evolution is estimated and forecasted by applying the Lotka–Volterra model, which describes the competitive interaction of species for a common supply. Genetic algorithms are also deployed for the estimation of the model's parameters.

Findings suggest that Linux can survive competition, even in a highly concentrated market, while Mac OSX is mostly benefited by the existence of Linux. As one step further, the study performs a sensitivity analysis of the possible effects on market structure induced by a rise in Linux adoption and identifies the conditions under which market structure can dramatically change, even to a competitive one. Results can provide valuable inputs for managerial decisions and strategic planning to the players of software markets.

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## 1. Introduction

Market structure and the degree of competition had long attracted the interest of researchers [1], as they play an important role in studying market power, business behavior and the performance of market players. In the case of software industry most market sectors are characterized by a tendency to high concentration. This is mainly due to the fact that software has some special attributes that create conditions favorable to a monopolistic behavior [2]. Network and lock-in effects on both demand and supply sides, together with the high switching costs, create favorable conditions for a potential monopolist. Firms may compete for prices, quality, innovation; they may even compete for the monopoly.

The emergence of Open Source Software (OSS) during the last decade, has been claimed to be able to offset this problem by changing the rules of competition in the market [3]. The innovative development model of OSS enabled the reduction of the high fixed development costs of proprietary software. As a result, many firms were able to overcome the high entry barriers and appear in the field of market competition, by adopting new or adapting their old business models towards OSS [4]. These new OSS business models have managed to gain substantial market shares from the established incumbents, indicating that OSS can be the solution for the software's tendency for monopolistic markets.

A very popular business model adopted by software firms is the creation of proprietary software, which has been derived by incorporating large or important parts of OSS code. Firms that adopt this strategy also maintain or support OSS communities that produce open source software, offered for free. This is the case for instance of IBM's WebSphere which has used the Apache web server as a key infrastructure component [5], MySQL with a dual licensing strategy, Apple's Mac OSX operating system and many others. The derived proprietary software can be placed in a third software category; the other two categories being the proprietary and open source software. For the purposes of this study this software category is defined as 'partly OSS.'

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As a result, the study of the evolution of the market structure, due to the existence of OSS, is considered of great interest for both research and practice. Although a number of studies have tried to model competition in software markets due to OSS (e.g. [6–14], etc.), most of them are mainly qualitative, based on theoretical models, which are not able to estimate actual evolution of the market structure. Moreover, they consider duopolistic markets with two kinds of software: OSS and proprietary. None of them examines the interactive competitive effects among the three kinds of software OSS, proprietary and partly OSS. Motivated by this gap in the literature, the purpose of the present work is to study the evolution of the market structure and concentration, as formulated due to the existence of OSS. The study considers a highly concentrated market, the desktop (DT) and laptop (LP) operating systems sector, in order to provide some insights of the potential of OSS even in the case of high market concentration. Using historical data, this paper aims to study the competition in the market and answer the following research questions:

How is the DT and LP operating systems market shaped? Is there an equilibrium? Will Linux survive competition at the equilibrium? Does the market concentration change? Are there any conditions under which market structure can dramatically change?

Based on concepts of population dynamics and organizational ecology, the study analyzes the evolutionary and competitive dynamics of the three leading players of the market, namely the OSS Linux, the partly-OSS Mac OSX and the proprietary Windows operating systems. Market evolution is estimated and forecasted by applying the Lotka–Volterra competition (LVC) model, which describes the competitive interaction of species for a common supply [15,16]. As one step further, the study performs a sensitivity analysis of the possible effects on market behavior, induced by a rise in Linux adoption. Such a rise could be attributed to an organizational change of policy towards Linux adoption, as for instance in the public sector, following a governmental initiative. In this case, the Lotka–Volterra model is reformed to accommodate different adoption levels of the Linux operating system. Results demonstrate the effects of such policy on market concentration, according to different levels of Linux adoption. Findings also reveal useful implications for practice, in terms of the role of OSS and its derivative partly-OSS products in markets with high concentration.

The main outcomes, which also define the importance of contribution of the proposed methodology, are the estimation of the modeled system dynamics, the provision of forecasts regarding market equilibrium and the estimation of the “churn effect,” which reflects the level of users’ switching among the operating systems. The model also provides information on the survival or extinction of each species, due to the competition effects and the market structure at the equilibrium.

Although a number of alternative modeling approaches for market evolution taking into account competitive effects in the diffusion process exist in literature, probably the most characteristic based on the Bass diffusion model [17–24], they are not able to model competition explicitly. Thus, they cannot be used for equilibrium analysis and estimation of the churn effect. Moreover, the Lotka–Volterra approach can also reveal interactions, or unexpected market behaviors, such as mutualism, that may guide strategic planning. Therefore, they have been widely applied in a number of studies regarding competition in the Information and Communication Technologies (ICT) sector and other technology markets [25–31]. Yet, the method has never been previously applied in the operating systems market considering a three species competition. Also, among the innovative elements of the methodology, is the deployment of genetic algorithms (GA) for the estimation of the LVC model’s parameters. Genetic algorithms [32,33] are adaptive heuristic search algorithms, designed to simulate processes in natural systems necessary for evolution. They are increasingly used as a novel method for parameter estimation, because of their efficiency to produce better results, as compared to the often used classical methods of nonlinear least squares (NLS), maximum likelihood estimation (MLE), etc. [34].

The rest of the paper is structured as follows: [Section 2](#) gives an overview of the operating systems market. [Section 3](#) provides the necessary theoretical background of population dynamics and ecological modeling, as well as the mathematical equations that describe these concepts. Based on these theoretical concepts, the methodology developed for the case of the operating systems market is presented. The empirical analysis and results are illustrated in [Section 4](#). [Section 5](#) explores the effects on market structure induced by migration from Windows to Linux at an organizational level, while [Section 6](#) discusses the managerial implications of the study. Conclusions together with directions for future research are provided in [Section 7](#).

## 2. The operating systems market

Operating system (OS) is a vital component of a computer system, therefore its existence can be traced back to the 50’s, with the appearance of the first computers. For a long time, OS was offered bundled with the computer, free of charge and with source code open. In the 1970’s, however, software unbundling together with firms’ policy to keep the source code hidden has created new market prospects for firms to make profits out of software. Operating systems competition started mainly for servers running on mainframes and supercomputers. With the introduction of the personal computers (PC) and more powerful workstations in the early 1980s, the OS market was widened to non-technical users that could have a PC even at home. Toward the end of the 1980s, simple PC-based client–server systems also came into existence. This has, in turn, induced greater competition among software firms for OS shares. Windows, proved to be a market winner when version 3.0 was released in May 1990. Windows was often criticized as lack-luster; however, since it was light-weight and compatible with existing MS-DOS applications, it became a success overtaking IBM’s OS/2. Microsoft and Novell were dominating the PC desktop and server markets respectively, until Microsoft introduced the Windows server OS in 1993, which rapidly superseded Novell’s Netware [35].

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