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The competition and equilibrium analysis of LCD TV and PDP TV

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ABSTRACT

This study has investigated the dynamic competitive relationship between PDP TVs and LCD TVs by means of their quarterly shipments. The renowned Lotka–Volterra competition diffusion model has been adopted to conduct the empirical analysis with the Lyapunov function to carry out equilibrium and stability analysis, and estimate the domain of attraction which describes the trend and phenomenon of TV shipments. The results illustrate that there is good fitting performance while adopting this model. The competitive relationship can be viewed from the perspective that the LCD TV is the prey while the PDP TV is the predator. The possibility, nevertheless, for dropping the price of LCD TVs is an advantage of the attractiveness of the product which can be noted in higher growth rate than PDP TVs. With respect to the equilibrium stability analysis and estimated domain of attraction, 40- to 49-inch PDP TVs will not disappear from the market, but will generate a stable equilibrium with LCD TVs and sales volume presents simultaneous increase or decrease. In the supply and demand analysis, LCD TVs present a surplus of supply from 2008; therefore, how to conduct appropriate inventory management will be an emerging issue.

1. Introduction

Before 2004, the wrestling between LCD TV (Liquid Crystal Display TV) and PDP TV (Plasma Display Panel TV) was prominent in the global flat monitor market; both of which were well matched in strength. According to the data from DisplaySearch, the shipment of 33- to 39-inch PDP TVs in 2003 was 148,000, while LCD TVs was 67,000. Nevertheless, the technological development of the LCD industry was beyond expectation when Sharp established its first Gen6 fabs in 2004Q1.

As for the shipment of 40- to 49-inch TVs, in 2005Q4, the shipment of PDP TVs was 1.776 million, while for LCD TVs it was only 498,000. The amount of shipments of PDP TVs was considerably larger than that of LCD TVs. Since 2006, however, there was a dramatic reversal in the market of 40-inch slim TVs, which mainly resulted from simultaneous mass production of Samsung's second Gen7 fabs, LPL's Gen7.5 fabs, and Sharp's Gen8 fabs, and thereby reduced the costs. Inevitably, 40-inch TVs as the mainstream ensued. When LCD TVs and PDP TVs played as competitors, it should be noted that the amount of shipments of PDP TVs, in 2006Q4, was 2.09 million, while that of LCD TVs grew considerably to 2.96 million.

Moreover, the capability of the TFT-LCD (Thin Film Transistor Liquid Crystal Display) panel factories had been improved from Gen7 fabs since 2006Q4. The competition for PDP TVs in the market of 50-inch TVs has grown fiercely since then. This study, considering the increased competition between PDP TVs and LCD TVs, adopted the product competition diffusion model and the Lyapunov stability equilibrium analysis to investigate the issues of the dynamic competitive relationship between LCD TVs and PDP TVs, and investigates whether PDP TVs will disappear in the market under 50-inch or if there exists a balance between them.

The diffusion model is mainly applied to conducting forecasting for product life cycles and product purchases. By employing the model, manufacturers can be informed of which period of the life cycle the product will enter, as well as how the customer will

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make decisions in certain periods. Accordingly, the manufacturers are then able to formulate appropriate policies in production, marketing, and finance.

Since Bass [1] carried out assessments of new products in terms of the quantitative model, the Bass Diffusion Model, highly regarded as the enlightenment, had been utilized to investigate diffusion patterns and demand forecasting. Afterwards, many studies, based on the Bass Model, endeavored to expand, incorporate, modify and introduce new methods for the purpose of reflecting the complexity of the market. Jain and Rao [2] suggested that the price of the product had an effect on the whole market potential, while Jones and Ritz [3] claimed that an increase in the number of the retailers would affect the whole market. Lilien et al. [4] verified the medicines diffusion situation with the product repeat-purchase model. Norton and Bass [5] declared the multi-generation substitute diffusion model and applied it to obtain high-technology products substitution and diffusion for each successive generation. However, most previous diffusion models extended from Bass [1] assumed a monopolistic market, which in reality process different characteristic of interactive competitive markets.

When tracking product development and sales of LCD TVs and PDP TVs, a typical competitive market has been revealed. The Lotka–Volterra equation, which was developed to model the interaction between two competing species based on the logistic curve, has been adopted to the situation of competitive markets. Modis [6] analyzed the behaviour of common stock-bond interactions by the Lotka–Volterra model, as if they were species competing for investors' resources. Furthermore, Modis [7] focused on the topic of genetic re-engineering of corporations for discussion, described the competitive dynamics in a market niche occupied by two competitors, and classified the types of competitive roles according to the models' parameter. Lee et al. [8] analyzed the dynamic competitive relationship on the Korean stock market, and verified that the competitive roles would change as time passed. On the other hand, Maurer and Huberman [9] adopted the Lotak–Volterra model to explore the effects of competition among web sites, and how they affected the market. Furthermore, Kim et al. [10] explored the Korean mobile phone market and found a commensalisms relationship, while Lope and Sanjuan [11] analyzed the competition dynamics of web sites on the Internet by way of stability analysis to establish a series of rules, which are useful for defining strategies on the Internet market.

Domain of attraction means that the set in this region will converge to the origin. Several studies have focused on the domain of attraction of the zero equilibrium point from nonlinear autonomous systems. To obtain an estimate of the domain of attraction, Genesio et al. [12] and Chiang et al. [13] based on topological considerations, while Tesi et al. [14] and Chesi et al. [15] solved the domain of attraction by recasting it as a linear matrix inequalities (LMIs) feasibility problem. The usual mathematical tool used for analysis of the domain of attraction is Lyapunov's method, which provides a sufficient condition for local stability, although it is not easy to find a Lyapunov function that can be used as a certificate for the whole domain of attraction; for example, Davision and Kurak [16] and Levin [17] have used quadratic functions. With recent developments from Parrilo and Lall [18] and Wang et al. [19] using algebra and sum-of-squares techniques, it is now possible to solve a Lyapunov function with a more general polynomial form. Positive definiteness properties are replaced by sum-of-squares constraints which can be efficiently solved by using convex optimization. The SOSTOOLS [20] toolbox for MATLAB has been developed as an easy computational tool to solve the problems that utilize the sum-of-squares technique. Jarvis-Wloszek [21] found a Lyapunov function within some specified semi-algebraic region.

Accordingly, this study intends to adopt the Lotka–Volterra competitive model to describe the competitive relationship between PDP TVs and LCD TVs. Regarding data collection for empirical analysis, the PDP TV and LCD TV quarterly shipments published by DisplaySearch (http://www.displaysearch.com) have been utilized to explore the competitive effect, and to estimate the demand function. Furthermore, the dynamic competitive relationship can be investigated by means of parameters, which will be employed to find the equilibrium, if one actually exists. In respect to the stability equilibrium analysis, two-phase procedures are proposed: (i) choosing a Lyapunov function to prove local asymptotic stability of the equilibrium; and, (ii) estimating the domain of attraction associated to that particular Lyapunov function.

2. Model description

2.1. Lotka–Volterra equation

An s-shape pattern exemplifies the growth of various species (products) under competition. There are two turning points in an s-shape pattern: one is the exponential rise resulting from the capability of species to multiply; the other is the slow-down of niche-saturation generated from the competitive squeeze caused by the limited space, which is the so-called intraspecific competition. The s-shape pattern, however, is no longer applicable because the rate of growth between different species can interfere with each other in many ways. It is necessary, therefore, to take the interaction between the species into consideration, which is referred to as interspecific competition.

With the Lotka–Volterra competitive mode, the competitive relationship between two species in the same environment market can be represented by the following two differential equations:

$$\frac{dM}{dt} = (a_m - b_m M + c_{mn} N)M = a_m M - b_m M^2 + c_{mn} MN \tag{1}$$

$$\frac{dN}{dt} = (a_n - b_n N + c_{nm} M)N = a_n N - b_n N^2 + c_{nm} NM \tag{2}$$