

# RELATIONSHIPS OF SMARTPHONE SALES BETWEEN NOTRH AMERICA AND ASIA MARKETS

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## ABSTRACT

This investigation employs the Lotka-Volterra model to explore the competitions of smartphone sales between Asia and North America regions. The parameter estimation results show that the smartphone sale growth in Asia substantially promotes that in North America, whereas the smartphone sale growth in North America curtails that in Asia. The smartphones are first sold to North America. As the smartphone sale in North America increases, the sale in Asia decreases. Until the production capacity of smartphone is stable and large enough, the sale in Asia increases. When smartphones get popular in Asia, the widespread of smartphone entertainments and commercial activities in Asia stimulate the smartphone sales in North America.

**Keyword:** Smartphone, Asia, North America, Product life cycle, Capacity

## INTRODUCTION

This investigation employs the Lotka-Volterra model to explore the competitions of smartphone sales between Asia and North America regions. The sales volumes of smartphone from each company's segment reporting income statements are summarized into the global sale volumes of the two specific regions. Previous studies analyzed the trade interdependency among various regions, but few studies have highlighted the quantitative evidence of end user relationships. Thus, this study utilizes smartphone sale volumes to predict the competitive relationships of market sales between Asia and North America. Due to advanced communication specifications and high income, consumers in North America accept smartphone easily [1]. North America market became the major market of smartphones when smartphone entered into market. Although North America was once the global greatest consumption area of smartphone before the second quarter of 2011, the cumulative sales volume of smartphone in Asia is over that in Asia since 2011 due to the huge population and economic development in Asia. As the manufacturing capacity of smartphone is limited, a great amount of smartphones sold to one region would reduce the smartphone volumes sold to other regions. As the smartphone sales volumes in North America increase, the sales volumes in Asia decrease. In addition, people use smartphones for the purpose of entertainment, wireless communication, global positioning and media. As Asia and North American enterprises implement worldwide entertainment, media, game and commercial activities through smartphones, the interrelationships of smartphone sales between Asia and North America is increasing, affecting the global smartphone industry. The feature of a competitive-cooperative relationship, which exists in smartphone sales across different areas. However, previous studies focused more on the trade interdependency of products when analyzing the economic relationship [2,3,4], and generally neglected sale dependency. Thus, this study explores the relations of smartphone sales between Asia and North America regions.

This work for the first time utilizes the Lotka-Volterra model to objectively quantify the competitive and cooperative relations of sales relations between North America and Asia. Most previous studies applied S-curve diffusion models to determine the market dynamics of durable products [5]. Shao [6] studied the adoption of expert systems and utilized the diffusion models. Chien et al. [7] further modified diffusion model to forecast the diffusion of semiconductor product demand. However, these

previous models excluded the analysis of reciprocal cooperation or competition among various consumption regions. If we apply the conventional diffusion model to explain the smartphone sales volumes into Asia and North America, the estimation results may be biased. Tsai, et al. [8], Tsai, et al. [9] or Tsai and Li [10], typically use Lotka-Volterra models to describe the competitive interaction between two groups [11,12]. The Lotka-Volterra model considers the self-diffusing evolution situation based on the traditional S-shape curve [7,13] and includes competitive interaction between two groups [14]. Thus, the purpose of this study is to use the Lotka-Volterra model to consider these interactive effects and predict smartphone sales volumes in North America and Asia. The rest of this paper is organized as follows: Section 2 state our methodology. Section 3 presents a summary of the results of the analysis. Finally, section 4 offers a conclusion.

## METHODOLOGY

### Lotka-Volterra model

The Lotka-Volterra model uses the logistic equation and a term that accounts for the interaction of smartphone sales, which is expressed by the following two differential equations:

$$\frac{dX}{dt} = (a_1 - b_1X - c_1Y)X = a_1X - b_1X^2 - c_1XY \quad (1)$$

$$\frac{dY}{dt} = (a_2 - b_2Y - c_2X)Y = a_2Y - b_2Y^2 - c_2YX \quad (2)$$

where  $\frac{dX}{dt}$  and  $\frac{dY}{dt}$  denote the quarterly sales volume of smartphone from Asia and North America at each quarter  $t$ .  $X$  and  $Y$  are the cumulative sales volume of smartphone from Asia and North America up to quarter  $t$ . The cumulative sales volume calculation starts with the first quarter of 2008, and accumulates quarterly until the fourth quarter of 2013. Additionally,  $X^2$  and  $Y^2$  refer to the same sales volumes interacting with itself, while  $XY$  and  $YX$  denote competing sales volume interactions. Equations (1) and (2) contain all of the fundamental parameters that affect the growth rates of Asia and North America sales volumes. Regional competition and cooperation can be determined through the parameters  $a_i$ ,  $b_i$  and  $c_i$ . Parameter  $a_i$  represents the ability of Asia (or North America) to multiply or grow its sales volumes by itself. The sales volume in one region will stimulate the growth of its sales volume, so this term  $a_i$  should have positive signs. Parameter  $b_i$  refers to the limitation parameter of Asia (or North America). Parameter  $c_i$  represents how Asia and North America sales volumes affect each other. This work utilized the parameters  $a_i$ ,  $b_i$  and  $c_i$  to examine how Asia and North America smartphone sales volumes are related. The proposed Lotka-Volterra model forms a pair of nonlinear differential equations, which are solved numerically using the genetic algorithm (GA) approach combined with the simultaneous nonlinear least squares (NLS) method in order to optimize the parameters. The reason of adopting GA approach by this work is to avoid inadequate initial values (Tsai, 2013b). This study initially used GAs to randomly select 3,000 different sets of initial values and applied the simultaneous NLS method to solve numerically the nonlinear Equations (1) and (2). 3,000 sets of estimated parameters  $a_i$ ,  $b_i$ , and  $c_i$  are obtained so that this work can use the  $t$ -statistics to examine

directly the statistical significance of the competitive evolutionary process between Asia and North America.

## Data and sample

Quarterly smartphone sales volumes to Asia and North America are obtained from Gartner technology research database. The study period lasts from the first quarter of 2008 to the fourth quarter of 2013, for a total of 24 quarters. This work divides our sample period into two periods: the in-sample period from the first quarter of 2008 to the second quarter of 2013 and the out-sample period from the third quarter of 2013 to the fourth quarter of 2013. Parameters of the proposed model are optimized using the data in the in-sample period. This work utilized the estimation parameter results to illustrate the relations of smartphone sales across various areas. The forecasting capabilities of different models are compared using the data in the out-sample period.

## Empirical Results

The 3,000 sets of estimated parameters were optimized using the smartphone sales volumes between Asia and North America from the first quarter of 2008 to the second quarter of 2013. The means and standard deviations of the 3,000 sets of optimized parameters of the proposed Lotka-Volterra model are shown in Table 1. All 3,000 sets of the estimated parameters  $a_i$ ,  $b_i$ , and  $c_i$  are approximate; therefore, the standard deviations of the 3,000 sets of the estimated parameters are fairly small. Although the 3,000 sets of the initial values are different, the optimized parameters are similar and stably located within a reasonable range. This finding suggests that our simulation involving the GA approach, which is combined with the simultaneous NLS method, generates stable and reliable parameters with only slight deviation. According to the  $t$ -statistics results of Lotka-Volterra model, the statistical significance for the 3,000 sets of estimated parameters are all maintained at a level of less than 1%.

**Table 1**

The means and standard deviations of the estimated coefficients of the Lotka-Volterra model over 3,000 iterations of smartphone sold into Asia and North America

Asia			
	$a_1$	$b_1$	$c_1$
Mean	$2.035303 \times 10^{-1***}$	$-3.045922 \times 10^{-8***}$	$1.882183 \times 10^{-7***}$
Standard Deviation	$6.192762 \times 10^{-10}$	$2.096070 \times 10^{-15}$	$4.906268 \times 10^{-15}$
$t$ -statistics	$1.800136 \times 10^{10}$	$-7.959275 \times 10^8$	$2.101223 \times 10^9$
North American			
	$a_2$	$b_2$	$c_2$
Mean	$1.856833 \times 10^{-1***}$	$3.397439 \times 10^{-7***}$	$-5.315913 \times 10^{-8***}$
Standard Deviation	$4.529592 \times 10^{-9}$	$4.134051 \times 10^{-15}$	$1.895469 \times 10^{-15}$
$t$ -statistics	$2.245299 \times 10^{10}$	$4.501284 \times 10^9$	$-1.536108 \times 10^9$

\*Significant at the 10% level. \*\*Significant at the 5% level. \*\*\*Significant at the 1% level.

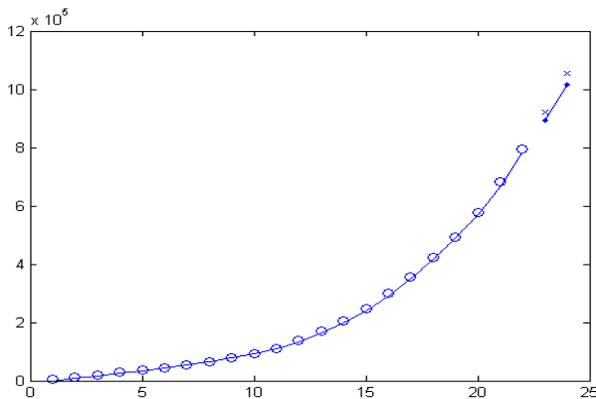
The self-effect parameters of North America,  $b_2$  are positive, indicating that North America sales volumes would compete among themselves in the same region. Because smartphones are first entered

into North America and their diffusions achieved the mature stage of product life cycle in North America, the marginal growth of smartphones sold in North America is decreasing. The more the smartphones sold into North America, the less extent in which the smartphone sales volume will grow. This suggests the severe saturation pressure existing within North America areas. As smartphone sales volumes amount approaches market saturation, the growth rate of sales volume decreases. In other words, the smartphone consumption faces heavy internal rivalry within the same region.

By contract, the self-effect parameters of Asia,  $b_1$  are negative, indicating that Asia sales volumes would stimulate sales growth in the same region. The marginal growth of smartphones sold in Asia is increasing. The more the smartphones sold in Asia, the greater extent in which the smartphone sales volume will grow. This suggests the great effect of word of mouth existing within Asia areas. Because smartphones entered into Asia later than North America, Asia smartphone market is far from market saturation until now, the incumbent Asia consumers of smartphones share the functions of entertainment, wireless communication global positioning and media to other people and attract the successive Asia consumers to purchase smartphones. Thus, the strong effect of word mouth accelerate the diffusions of smartphones in Asia.

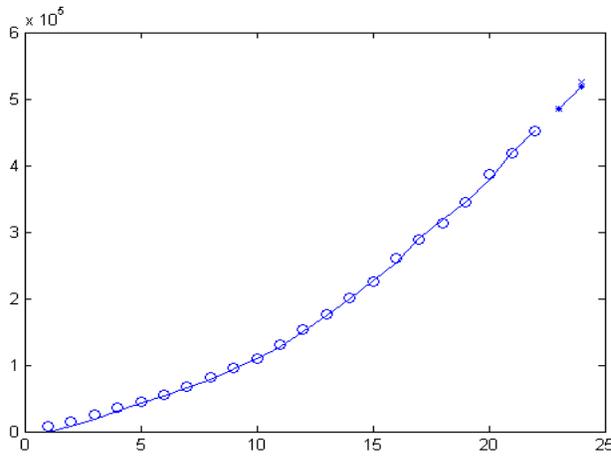
On the other hand, the interaction parameter of the Asia sale volumes affected by North America,  $c_1$ , is positive and significant, indicating that the Asia sales volume is squeezed by the massive stress of North American sales volumes. The interaction parameter of the North American sale volumes affected by Asia,  $c_2$ , is negative and significant, indicating that the Asia sales volume enhances North America sales volumes. Sale growth in Asia substantially promotes that in North America, whereas the sale growth in North America curtails that in Asia. North America is the target market of smartphones. Thus, the smartphone firms are first sold to North America. As the smartphone sale to North America increases, the sale in Asia decreases. Until the production capacity of smartphone is stable and large enough, the sale to Asia increases. When smartphones get more and more popular in Asia, the widespread of smartphone entertainments and commercials in Asia stimulate the smartphone sales in North America.

This work then compare the actual and the simulated cumulative sale volumes. Figures 1 and 2 depict the actual and simulated cumulative sales volumes using the proposed Lotka-Volterra model for Asia and North America sales volumes, respectively in the in-sample and out-sample periods. The line in Figures 1 and 2 depict the predicted sales volumes. Obviously, the predicted sales volume is extremely close to the actual volumes predicted by our proposed Lotka-Volterra model. Figures 1 and 2 summarize the results of the model goodness and forecast accuracy in in-sample and out-samples, respectively.



**Figure 1**

The actual and simulated sales volumes of smartphones sold into Asia



**Figure 2**

The actual and simulated sales volumes of smartphones sold into North America

### CONCLUSIONS

This study used the Lotka-Volterra model to investigate smartphone sales and considered the interactive dependence among various regions in the smartphone industry. Specifically, how consumption centers shifted from North America to Asia is explored by focusing on the intimate relationship of competition and cooperation between smartphone market in Asia and North America. Empirical results of this investigation show that the Lotka-Volterra model can be used to determine the reciprocal influence among sales volumes of these two consumption regions in the smartphone industry.

Sale growth in Asia substantially promotes that in North America, whereas the sale growth in North America curtails that in Asia. North America is the target market of smartphones. Thus, the smartphones are earliest sold to North America. As the smartphone sale to North America increases, the sale in Asia decreases. Until the production capacity of smartphone is stable and large enough, the sale to Asia increases. When smartphone gets more and more popular in Asia, the widespread of smartphone entertainments and commercials in Asia stimulate the smartphone sales in North America.

Analytical results demonstrate that smartphone sale in Asia substantially promotes sales growth within Asia, whereas the smartphone sales in North America curtails sales growth within North America. A possible explanation for this phenomenon is that, in the smartphone market, North America and Asia are at the mature and early stages of the product life cycle. Thus, the sale of smartphones deters the sale growth in North America, while the sale of smartphones accelerates the sale growth in Asia. Regarding the interaction effect between Asia and North America markets, the parameter estimation results of the Lotka-Volterra model show that the smartphone sale growth in Asia substantially promotes that in North America, whereas the smartphone sale growth in North America curtails that in Asia. As the smartphone sale in North America increases, the sale in Asia decreases. Until the production capacity of smartphone is stable and large enough, the sale in Asia increases. When smartphone get more and more popular in Asia, the widespread of entertainment, commercial, and communication activities in Asia stimulate the smartphone sales in North America.

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