Applying bass model and KK model to forecast multinational diffusion in LCD TV industry: Empirical evidence from Asian and North America

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In this high-tech era, the internet, globalization and multinational companies are causing increasingly rapid changes in the environment. They are also affecting the economic patterns of the global market, changing consumer purchasing behavior. Due to research and marketing process of a new product or new technology development, enterprises are no longer the focus of the single market strategy. Enterprises are considering information in global market as how to achieve multinational market diffusion quickly and effectively. This study adopts Bass models and KK models based on Bass (1969); Kumar and Krishna (2002) and application methods of nonlinear least squares (NLS) for LCD TV market to estimate the effects of diffusion parameters in the multinational models. This study expects to find these parameters between multinational influences and to compare Bass Models and KK models as explained in the multinational market for consumers to buy a new product of differences. The study also estimates the impacts on the multinational market of the rise of the internet to help enterprises develop more effective marketing strategies.

Key words: LCD TV Industry, innovation diffusion, bass model, KK model, multinational diffusion model.

INTRODUCTION

Meade and Islam (2006) reviewed the literatures related to the innovation diffusion, so that the changes in the market can be seen more clearly. Whether in the form of new products entry into the market (that is, the new mobile phone), new technology adopted (that is, agricultural technology), implementation of new policies (that is, waste classification), new trends (that is, hip hop music), formation of new habits, or even the spread of epidemics, the phenomenon is called diffusion of innovation. New product sales growth in a given nation or society is affected by many factors (Rogers, 1995). Socio-contagion (or word-of-mouth) has been found to be the most important factor that characterizes the diffusion process (Bass, 1969; Moore, 1995; Kumar and Krishnan, 2002).

Bass (1969) provided a forecast model of the diffusion of products, based on which enterprises are able to respond to new products entry into the market that solved the problem of the uncertainty of marketing process. Many enterprises in the United States adopt this model, including Kodak, Radio Corporation of America (RCA), IBM, and AT and T. Modeling developments in the period 1970 onwards have been in modifying the existing models by further adding more flexibility in various ways (Meade and Islam, 2006). In recent years, because of their large populations, many developing countries actually have a lot of potential buyers. As a consequence, when trying to introduce a new product to a developing country, they must consider an international market whose size is larger than that of the developing country's. Not only will they observe the diffusion process in two or more countries differently, but they will also observe some interaction among them as well, especially if the two or more societies mingle with each other.

A number of papers since 1990 have followed the global...
trend of focusing on multinational product acceptance and have extended the traditional single-market scope to explore problems and issues related to international diffusion (Dekimpe et al., 2000). A key issue in multinational diffusion, especially with respect to order of entry, is the mutual influence of diffusion processes in various countries. One of the major findings of the studies to date on cross-country influences is that the entry time lag has a positive influence on the diffusion process; that is, countries that introduce a given innovation later show a faster diffusion process and a shorter time to takeoff. This cross-country influence has been called the lead-lag effect; however, influence can be multidirectional, current demographic changes are affecting cross-country influences and raising new challenges for global marketers (Desiraju et al., 2004; Elberse and Eliashberg, 2003; Van Everdingen et al., 2009; Peres et al., 2010).

The optoelectronics industry, following the development of the semiconductor industry, is a focus in the government’s “two trillion, two star” high-tech development strategy. The thin film transistor liquid crystal display (TFT-LCD), as a high-value product, significantly affects industry supply chain. It can stimulate related materials, equipment, and application of the upstream and downstream development domestically; it can also attract foreign investment, inducing foreign enterprises to set up factories in Taiwan. Therefore, it is regarded as an engine of economic development. Taiwan, South Korea and Japan are the major TFT-LCD producing countries. In the large-sized TFT-LCD main application products, LCD TV has become the most important TFT-LCD applications.

LITERATURE REVIEW

The bass model of diffusion

Given the cumulative number of dimensions of the discussion, innovation diffusion model is used by a process of showing an S-shaped curve (Figure 1). According to Rogers (1995), due to innovation diffusion resulting from the heterogeneity of the population structure that affected innovation, Bass (1969) provided further modeling Bass Model based on hazard function, the equation is:

\[ P(A|B) = \frac{P(A \cap B)}{P(B)} = P(t) = \frac{f(t)}{1 - F(t)} = p + qF(t) \]

(1)

\[ f(t) = (p + qF(t))(1 - F(t)) \]

(2)

Innovators adopt innovation (innovative coefficient, \( p \)) and other imitators adopt innovation (imitating coefficient, \( q \)), in a time \( t \), the probability that a potential adopter adopts at time \( t \) is driven by \( (p + qF(t)) \), where \( F(t) \) is the proportion of adopters at time \( t \). Relating the similarity of innovation diffusion with the spreading of an epidemic, imitation is often called a contagion effect. This model of the basic assumptions is as follows:

1. Does not repeat the purchase of consumer products,
2. Model does not consider any variables (advertising, price, etc.), and
3. Model for the demand model does not consider the supply side.

Let \( m \) represent market potential, then

\[ n(t) = mf(t) \]

\[ N(t) = mF(t) \]

Where, \( n(t) \) is the number of new adopter at time \( t \). \( N(t) \) is the cumulated number of new adopter at time \( t \). Therefore, from Equation 1, sales at time \( t \) can be described as:

\[ n(t) = \frac{dN(t)}{dt} = mf(t) = m(p + qF(t))(1 - F(t)) \]

\[ = \left( p + \frac{q}{m}N(t) \right)(m - N(t)) \]

(3)

\[ = p(m - N(t)) + \frac{q}{m}N(t)(m - N(t)) \]

In this equation, \( p[m - N(t)] \) means that at time \( t \), innovators, who were not influenced by the adopters before time \( t \), only by the mass media exterior influence adopt the new product. \( \frac{q}{m}N(t)[m - N(t)] \) means that at time \( t \), imitators, who imitate the adopters’ interior influence before time \( t \), adopt the new product. The equation also implies that at time 0, \( n(0) = p \times m \).

The KK model of diffusion

Since Bass (1969) provided the basic diffusion model, scholars have proposed models for all aspects of the question. To further propose amendment for the models, one can expect parameters in the models for better interpretation. With the advent of high-tech era and the rise of multinational corporations, enterprises will not only focus on the single market, but also on more than two markets. However, for enterprises to assess how effective product innovation is on the diffusion in different countries, different regions, and different markets, it is urgent for each enterprise to understand the information. Hence, Kumar and Krishnan (2002) are interested and perhaps challenged to analyze what would happen if a new product diffuses in parallel in two neighbouring, but
culturally different countries or regions.

Not only did they expect the diffusion process in the two countries to be different, but they also expected some interactions among them, especially if the two societies mingle with each other. This study is to propose a model based on Kumar and Krishnan (2002) that captures the lead-lag, lag-lead, and simultaneous effects. They will apply the model in two stages: first focusing on modeling the simultaneous effect and then including the lead-lag and lag-lead effects in that model. According to Bass et al. (1994), to capture the effect of diffusion in one country on diffusion in the other, they model the diffusion of each country in the lines of the Generalized Bass Model (GBM) as follows:

\[ f(t) = \left( p_i + q_i F_i(t) \right) \left( 1 - F_i(t) \right) x_i(t) \quad i = 1, 2, \ldots \]  

(4)

Where \( p_i \) is the innovation coefficient or external influence, \( q_i F_i(t) \) is the word of mouth effect, and \( x_i(t) \) is the current marketing effort as defined in the GBM. The current marketing effort term should include only those effects that are happening at time \( t \) because the effect of those efforts expended up to the previous time (that is, \( t-1 \)) is captured by \( F_i(t) \). Because their main focus is to model the impact of diffusion in the other country (say Country 2 or Region 2) on the country's (say Country 1 or Region 1) diffusion, they model \( x_i(t) \) as follows:

\[ x_i(t) = 1 + \left( b_{2i} \times \text{change at time } t \text{ in diffusion force of country } 2 \right) \]  

(5)

Here, \( 1 \) represents the natural time, the diffusion force is simply the cumulative adoption up to \( t \), and \( b_{2i} \) measures the impact of country 2's diffusion on country 1's diffusion. Then we have:

\[ x_i(t) = 1 + \left( b_{2i} \times \frac{dF_i(t)}{dt} \right) \]  

(6)

Thus, a similar differential equation can be derived for country 2's diffusion. These equations can further be reduced to yield:

\[ N_1(t) = m_1 F_1(t) \]

\[ = m_1 \times \frac{1 - e^{-(p_1 + q_1)(t + b_{21} F_1(t))}}{1 + q_1 e^{-(p_1 + q_1)(t + b_{21} F_1(t))}} \]  

(7)

\[ N_2(t) = m_2 F_2(t) \]

\[ = m_2 \times \frac{1 - e^{-(p_2 + q_2)(t + b_{21} F_1(t))}}{1 + q_2 e^{-(p_2 + q_2)(t + b_{21} F_1(t))}} \]  

(8)

Where, \( b_{21} \) and \( b_{12} \) are the influences of country 2 (or region 2) on country 1 (or region 1), and vice versa, respectively. \( n_1(t) = f(x_i(t); m_1) \) where \( f(x_i(t); m_1) = f(x_i(t); m_2) \) function \( F_2(t) = F_2(t; t; p_2, q_2, b_{21}) \), and so on. Thus, they find that country 1's sales growth is a recursive function and the parameters involved are \( p_1, q_1, p_2, q_2, b_{21}, b_{22}, \) and \( m_1 \). However, it does not explicitly depend on any variable other than \( t \). Specifically: it is not stated as a function of country 2's actual sales or cumulative sales.

Similarly the sales function. \( n_2(t) = f(x_i(t); m_2) \), where \( n_2(t) = f(x_i(t); m_2) \) function \( F_2(t) = F_2(t; t; p_2, q_2, b_{12}) \), where \( F_2(t) = F_2(t; t; p_2, q_2, b_{12}) \), and so on. This implies that country 2's sales growth is a recursive function of \( t \) alone and not of country 1's actual sales or cumulative sales. They can use the following Figure 2 to show the relations of innovation diffusion between the two countries.

**EMPIRICAL DEMONSTRATION**

Data source

The object of this study is the LCD TV. Shipments of the databases in Display Research and Topology Research Institute used statistical information. The databases include statistics on SAMSUNG, SONY, PHILIPS, SHARP, LG, TOSHIBA, PANASONIC, VIZIO, POLAROID, FUNAI, SANYO, TCL, HAIER, WESTINGHOUSE, JVC, and other brands.

The databases includes statistics on Japan, Taiwan, China (China includes Hong Kong, excludes Taiwan), and North America (N.A.) regions. According to data in Display Research and Topology Research Institute, they found that the current LCD TV is in a period of rapid development, diffusion rate has increased gradually. As it is difficult to obtain LCD TV information, they can only obtain information of 2006 through 2007.

Model estimation

This study will use the Bass Model and KK Model to empirically demonstrate the impact of country-to-country relations between the significant players, and then to discuss whether the diffusion will
Introduction of Innovation:
Simultaneous

Diffusion Effects:
Country 1 affects Country 2
Country 2 affects Country 1

Time of Introduction

Figure 2. Simultaneous effects. Reference source: Kumar and Krishnan (2002).

Introduction of Innovation:
Japan first
Taiwan later

Diffusion Effects:
Japan affects Taiwan

Time of Introduction

Figure 3. Lead-Lag effects for Japan-Taiwan.

Case 1: LCD TV industry began to develop in Japan, which was also the first market of the industry’s products. The products later entered the Taiwan market. So Japan is a lead country, while Taiwan is a lag country. Analysis of the relationship between the two countries’ framework is shown in Figure 3. They have completed the description of the multinational framework, and have further designed the two countries’ market formula, respectively, as follows:

\[
N_1(t) = m_1 F_1(t) = m_1 \times \frac{1 - e^{-(p_1+q_1)t}}{1 + \frac{q_1}{p_1} e^{-(p_1+q_1)t}}
\]  

(9)

Case 2: Japan is the first country of the development of the LCD TV industry and also the first market for its products, which later entered the Taiwan and China markets. The products entered China later than they did in Taiwan. So, Japan is a lead country, Taiwan and China are lag countries. Analysis of the relationship between the three countries’ framework is shown in Figure 4. They have completed the description of the multinational framework and further designed the three countries’ market formula, respectively, as follows:

\[
N_2(t) = m_2 F_2(t) = m_2 \times \frac{1 - e^{-(p_2+q_2)(t+b_{12}f_1(t))}}{1 + \frac{q_2}{p_2} e^{-(p_2+q_2)(t+b_{12}f_1(t))}}
\]  

(10)

\[
N_3(t) = m_3 F_3(t) = m_3 \times \frac{1 - e^{-(p_3+q_3)(t+b_{21}f_2(t))}}{1 + \frac{q_3}{p_3} e^{-(p_3+q_3)(t+b_{21}f_2(t))}}
\]  

(11)
Taiwan and North America are lag countries. In the LCD TV industry, because most of the creations of brands were in Japan and Taiwan, Japan and Taiwan would affect the adoption of brands in North America, rather than North America affecting Japan and Taiwan. Analysis of the relationship between the three regions' framework is shown in Figure 5. They have completed the description of the multinational framework, further designing of the three regions' market formula, respectively, as follows:

$$N_1(t) = m_1 F_1(t)$$

$$N_1(t) = m_1 \times \frac{1 - e^{-(p_1+q_1)(t+h_1 F_1(t)+b_2 F_2(t))}}{1 + q_1}$$

$$N_2(t) = m_2 F_2(t)$$

$$N_2(t) = m_2 \times \frac{1 - e^{-(p_2+q_2)(t+h_1 F_1(t)+b_2 F_2(t))}}{1 + q_2}$$

Case 3: This section discusses the diffusion of cross-regional model based on Kumar and Krishnan (2002), regional and regional discussions as to whether the impact will also be interactive. Since, LCD TV industry began to develop in Japan, entering the Japan market first and later the Taiwan and North America (N.A.) markets, with North America later than Taiwan, Japan is a lead country and

**Introduction of Innovation:**
- Japan 1 first
- Taiwan and China later, simultaneous

**Diffusion Effects:**
- Japan affects Taiwan and China
- Taiwan affects China
- China affects Taiwan
Table 1. Empirical result for the parameters of finishing.

<table>
<thead>
<tr>
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<th>Japan</th>
<th>Taiwan</th>
<th>China</th>
<th>N.A.</th>
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<td></td>
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<tr>
<td>p</td>
<td>0.000219</td>
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<tr>
<td>Japan-Taiwan</td>
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<td>p = 0.001094</td>
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<td>q</td>
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<tr>
<td>Japan-Taiwan-China</td>
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<td>p = 0.001174</td>
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<td>b_{12}</td>
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<td><strong>KK Model</strong></td>
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<tr>
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EMPIRICAL RESULTS

Results of the empirical demonstration of parameters estimation of the models are shown in Table 1. As can be seen from the results of the empirical demonstration, either Bass Models or KK models, as imitating coefficient models, are more than innovation coefficient. In line with expectations, only China's imitating coefficient for Japan-Taiwan-China on KK model is an exception. In the LCD TV industry, the effects of consumers' word-of-mouth communications are greater than those of external information and are accepted as part of the innovation efforts.

To the three cases of KK Models, multinational parameters were introduced. Although only very small values were acquired from the multinational parameters, they still increase the innovation coefficient and the imitating coefficient significantly. Values of multinational parameters are very small because too few data are available, when data integrity is accounted for; if the data have been obtained from a longer period of time, these values would be more significant. As a result, this study found that the imitating coefficient of the North American market has increased only marginally and that this market's potential may not grow and may even decline.

KK Models parameters are larger than Bass Models, although this study found that multinational parameters are not so significant. However, the KK Models affected by other countries or regions, innovation coefficient, imitation coefficient and market potential are larger than the parameters of Bass Models.

The purpose of this study is described in terms of market countries:

(1) Japan: Japan was the first to enter into the market, so its coefficient of innovation is lower than in other countries. However, they only recently obtained the data that can be found in the past two years in the imitation coefficient, so they can find that LCD TV market in Japan has been gradually developed.

(2) Taiwan: Since LCD TV industry brands have mostly been developed in Japan and Taiwan, with Japan entering the market earlier than Taiwan, innovation coefficient and imitate coefficient in the Taiwan market are higher.

(3) China: Because LCD TV entered into the China market quite late and China's rise as an economic power (that is, GDP) has been well known, the imitation coefficient is higher than in other countries, so China can be more easily adopted by the LCD TV.

(4) North America: As North America and Asia have cultural differences, North American consumers prefer large-scale products (such as Plasma Display Panel), and North America's innovative coefficient is higher than other countries. However, with the recent advances in

\[
N_3(t) = m_3 F_3(t) \\
= m_3 \times \frac{1 - e^{-(p_3 + q_3)(t + b_3 F_3(t) + b_2 F_2(t))}}{1 + \frac{q_3}{p_3} e^{-(p_3 + q_3)(t + b_3 F_3(t) + b_2 F_2(t))}} 
\]
LCD TV technology, LCD TV size has seen large-scale development, so North American consumers’ adoption of LCD TV is an indicator of fast diffusion.

**CONCLUSION AND IMPLICATIONS**

The parameter results of Bass and KK Models and innovation coefficients are less than imitating coefficients. In line with expectations, the LCD TV industry’s word-of-mouth effect among consumers is greater than the external effect. When setting their strategy, the enterprises should concentrate a majority of resources on upgrading product quality, functional diversification and further satisfying consumer needs. Another mechanism is to improve after-sales service to enhance consumers' goodwill towards products, a move that will further create a positive word-of-mouth effect.

This study has tried to summarize the following trends for the reference of future research. The increasing globalization of multinational corporations means consumers are no longer concerned with the response of the single market, but will also observe the trend of fluctuations around the world, and thus will increase multinational parameters. The rapid reactions in the supply chain mean that access to each market’s information is becoming more and more convenient and will further shorten the distances between the countries.

The economic situation (that is, GDP) of developing and developed countries will allow consumers to try new products, so, the number of new products will increase.

Friedman (2005) argues for Internet technology advances and hardware and software breakthroughs, claiming that these technologies are enhancing the knowledge-sharing web community. Hence, it is possible that parameters of a multinational corporation are not significant reasons to further enhance external effect and word-of-mouth effect while gradually reducing multinational cultural differences. Therefore, the effects on the Internet of promoting enterprise product strategy will be a focus that cannot be ignored.

The biggest difficulty faced in the process of this study is obtaining information. As the shipment data of major brands LCD TV are regarded as commercially confidential, only the monthly shipment information from the databases in Display Search and Topology Research Institute from 2006 - 2007 were available. Since, they had to surmount great difficulties to obtain information, the integrity of they data is more or less compromised. If complete information can be obtained, better models could be adopted to reflect multinational markets conditions. The following are their recommendations for future research on this topic:

1. This study followed the KK model to simulate multinational markets, and tried to simulate the regional markets as to whether the same can be applied to other regions.
2. Efforts should be made to obtain the data in question from the most primitive to the most recent sources so that the research results will better reflect the true market situation.
3. In this study, models of LCD TV industry have been constructed. Similar methods can be applied to other products and services, such as resource saving devices, the issue of bicycle shortage, the rise of Asia’s luxury fashion, and the software industry’s competitiveness.
4. Further detailed discussion should be held on the cultural differences of the multinational corporations, the impact of the Internet, of each country’s economy and other factors.

The major contribution of this paper is the development of a dynamic diffusion model, capable of describing the diffusion process of a multinational LCD TV industry, by incorporating the diffusion effect and simultaneous effects.

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