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Technological Entrepreneurship : Modeling and Forecasting the Diffusion of Innovation in LCD Monitor Industry

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***Abstract*—Following the optoelectronics industry is the development of the semiconductor industry strongly after the high-tech industry, a "two trillion, two star" one of the focal points. Recent years, the government putting in a lot of painstaking effort in Taiwan, let us LCD industry have brisk results, therefore, the LCD industry have the first place in the global market share.**

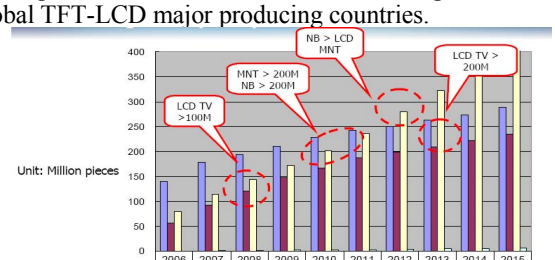
The wealth of research into modelling and forecasting the diffusion of innovations is impressive and confirms its continuing importance as a research topic. One of the earliest and most widely used models describing the diffusion of innovation is that of Bass （1969, 2004）. This study will build Bass Models and KK models based on Bass (1969) and Kumar and Krishna (2002), application methods of Nonlinear least squares (NLS) for LCD TV market to estimate diffusion parameters in the multinational models, which by KK Models into a multinational parameters effect, this study expect to find these parameter between multinational influence. Further to compare Bass Models and KK models explained in the multinational market for consumers to buy a new product of differences, and the impact on the multinational market based on the rise of the Internet to help enterprises develop more effective marketing strategies.

Keywords- Innovation Diffusion Model, Bass Model, KK Model, Multinational Diffusion Model, LCD Industry.

I. INTRODUCTION

The innovation diffusion model proposed by Bass （1969） has been widely used in the literature and has found applications in several areas. The understanding of the diffusion process of new products is a key factor in the strategic planning of a firm and, as such, justifies the number of contributions from different fields such as Industrial Economics, Strategic Management and Marketing. 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）.One of the earliest and most widely used models describing the diffusion of innovation is that of Bass （1969, 2004）.

The industry of LCD industry in Taiwan has experienced a phenomenal growth for the more than past decade, therefore it is regarded as the engine of economic development. Taiwan, South Korea and Japan are for the global TFT-LCD major producing countries.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
LCD MNT Panel	139	177	194	210	228	243	251	263	274	289
LCD TV Panel	56	92	120	147	167	187	198	210	222	234
NB Panel	80	114	143	172	202	236	280	322	366	410
Public Display Panel	0	1	1	2	2	3	3	4	5	6

* PS. LCD TV Panel is including LCD Monitor Panels used in LCD TV (MTV)

Figure 1. Large-size TFT-LCD market forecast source：Display Research

II. THE BASS MODEL OF DIFFUSION

The path the cumulative adoption of an innovation takes between introduction and saturation is generally modelled by an S curve. Examination of data sets suggests that this type of model is generally appropriate.（Meade & Islam 2006）, and of these, word of mouth has been found to be the most important factor that characterizes the diffusion process （Bass 1969, Moore 1995）.

In a time and the cumulative number of dimensions of the discussion, innovation diffusion model used by a process of showing S-shaped curve. According to Rogers（1962）due to innovation diffusion because the heterogeneity of the population structure affected innovation, Bass （1969）provided further modeling Bass Model based on hazard function, the equation is:

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

$$f(t)=\left(p+qF(t)\right)\left(1-F(t)\right) \quad (2)$$

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.)

(3) Model for the demand model does not consider the supply side.

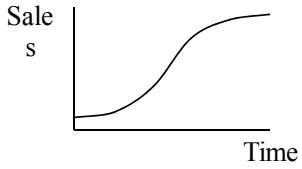


Figure 2. Growth of a new product

Reference source: Bass (1969). A new product growth for model consumer durables. *Management Science* (pre-1986); Jan 1969; 15, 5;

$$n(t) = mf(t)$$

$$N(t) = mF(t)$$

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 Eq. 1, sales at time t can be described as:

$$\begin{aligned} n(t) &= \frac{dN(t)}{dt} = mf(t) = m\big(p+qF(t)\big)\big(1-F(t)\big) \\ &= \left(p+\frac{q}{m}N(t)\right)\big(m-N(t)\big) \\ &= p\big(m-N(t)\big)+\frac{q}{m}N(t)\big(m-N(t)\big) \end{aligned} \quad (3)$$

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, $n(0) = p \times m$.

III. 2.THE KK MODEL OF DIFFUSION

The innovation diffusion model in several countries offers many benefits. Modeling the effect of different national cultures on the diffusion process gives insight into the effect of national differences on the rate of adoption of the innovation. Ganesh & Kumar（1996）, Ganesh, Kumar & Subramanian （1997）, Kumar, Ganesh & Echambadi（1998）, and other scholars in the study of the international innovation diffusion, they used Bass Model to design a framework for analysis diffusion to lead countries, lag countries and simultaneous countries. Kumar & Krishnan（2002） provided building KK models, further empirical demonstrate multinational effects in the multinational markets. They find new products in the lead countries with time-lag effects, lag countries known to be more effective, thereby increase the market potential, when the new products to entry new markets, will be more rapid diffusion.

According to Bass (2004), to capture the effect of diffusion in one country on diffusion in the other, we model the diffusion of each country in the lines of the Generalized Bass Model (GBM) as follows:

$$f(t) = \big(p_i + q_i F_i(t)\big)\big(1-F_i(t)\big)x_i(t) \quad i = 1,2,\ldots \quad (4)$$

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 (i.e., t-1) is captured by $F_i(t)$. Because our 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, we model $x_1(t)$ as follows:

$$x_1(t) = 1 + \begin{pmatrix} b_{21} \times \text{chage at time t in} \\ \text{diffusion force of country 2} \end{pmatrix} \quad (5)$$

Here, 1 represents the natural time, the diffusion force is simply the cumulative adoption up to t, and b_{21} measures the impact of country 2's diffusion on country 1's diffusion. Then we have

$$x_1(t) = 1 + \left(b_{21} \times \frac{dF_2(t)}{dt}\right) \quad (6)$$

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

$$\begin{aligned} N_1(t) &= m_1 F_1(t) \\ &= m_1 \times \frac{1 - e^{-(p_1+q_1)(t+b_{21}F_2(t))}}{1 + \frac{q_1}{p_1}e^{-(p_1+q_1)(t+b_{21}F_2(t))}} \end{aligned} \quad (7)$$

$$\begin{aligned} N_2(t) &= m_2 F_2(t) \\ &= m_2 \times \frac{1 - e^{-(p_2+q_2)(t+b_{12}F_1(t))}}{1 + \frac{q_2}{p_2}e^{-(p_2+q_2)(t+b_{12}F_1(t))}} \end{aligned} \quad (8)$$

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. $n_1(t)$ = function $(F_1(t); m_1)$, where $F_1(t)$ = function $(F_2(t), t; p_1, q_1, b_{21})$, where $F_2(t)$ = function $(F_1(t), t; p_2, q_2, b_{12})$, and so on. Thus, we 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_{12}, b_{21}, 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.

IV. EMPIRICAL DEMONSTRATION

A. Data source

The object of this study is the LCD industry. Shipments of the databases in Display Research and Industry and Technology Intelligence Services （ITIS）used the source of statistical information. In the databases, that includes statistics on the grounds SAMSUNG, SONY, PHILIPS, SHARP, LGE, TOSHIBA, PANASONIC VIZIO, POLAROID, FUNAI, SANYO, TCL, HAIER, WEST IN GHOUSE, JVC, and other brands. In the databases, that includes statistics on the grounds U.S.A, Japan, Korea, Taiwan and China regions.

According to data in Display Research and Industry and Technology Intelligence Services（ITIS）, we found that the current LCD is in a period of rapid development, diffusion rate increased gradually, as LCD difficult to obtain information, we can from 2007 period from January to March 2009 the monthly data to obtain information.

B. 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 occur at a more rapid pace. This section will use three kinds of multinational models for empirical research and proceed to analyze the results of the multinational markets.

According to Srinivasan & Mason (1986), this study adopts a program using a model of Non-linear least squares (NLS) method in statistical analysis software (SAS) to complete this iterative procedure. The study further adopts Bass Models and KK models based on Bass (1969) and Kumar & Krishna (2002), using the methods of Nonlinear least squares (NLS) for LCD monitor market to estimate the effects of diffusion parameters in the multinational models. In the process, the KK Models played a key role. This study expects to identify the influences of these parameters on the multinational interaction. Case 1. LCD monitor industry began to develop in Japan, which was also the first market of the industry's products. The products later entered the Japan market. So U.S.A. is a lead country, while Japan is a lag country. Analysis of the relationship between the two countries' framework is shown in Figure 3:

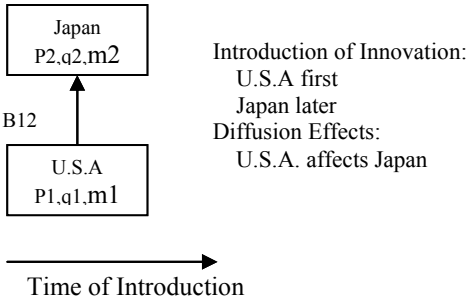


Figure 3. Lead-Lag effects for U.S.A.-Japan

Case 2. Since LCD monitor industry is from Japan began to develop, but also the first to entry the Japan market, and later entry the Korea market, so Japan is a lead country, Japan is a lag country. Analysis of the relationship between the two countries framework shown in Figure 4:

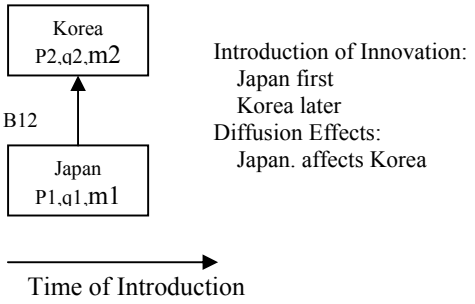


Figure 4. Lead-Lag effects for Japan-Korea

We have completed the description of the multinational framework, and have further designed the two countries' market formula, respectively, as follows:

$$N_1(t) = m_1 F_1(t) = m_1 \times \frac{1-e^{-(p_1+q_1)t}}{1+\frac{q_1}{p_1}e^{-(p_1+q_1)t}} \quad (9)$$

$$N_2(t) = m_2 F_2(t) = m_2 \times \frac{1-e^{-(p_2+q_2)(t+b_{12}F_1(t))}}{1+\frac{q_2}{p_2}e^{-(p_2+q_2)(t+b_{12}F_1(t))}} \quad (10)$$

Case 3. Japan is the first country of the development of the LCD monitor industry and also the first market for its products, which later entered the Korea and Taiwan markets. The products entered Taiwan later than they did Korea. So Japan is a lead country, Korea and Taiwan are lag countries. Analysis of the relationship between the three countries' framework is shown in Figure 5:

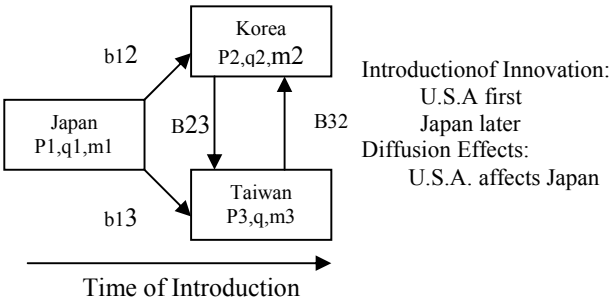


Figure 5. Lad-Lag and Simultaneous Effects for three countries

We have completed the description of the multinational framework and further designed the three countries' market formula, respectively, as follows:

$$N_1(t) = m_1 F_1(t) = m_1 \times \frac{1-e^{-(p_1+q_1)t}}{1+\frac{q_1}{p_1}e^{-(p_1+q_1)t}} \quad (11)$$

$$N_2(t) = m_2 F_2(t) = m_2 \times \frac{1 - e^{-(p_2+q_2)(t+b_{12}F_1(t)+b_{32}F_3(t))}}{1 + \frac{q_2}{p_2} e^{-(p_2+q_2)(t+b_{12}F_1(t)+b_{32}F_3(t))}} \quad (12)$$

$$N_3(t) = m_3 F_3(t) = m_3 \times \frac{1 - e^{-(p_3+q_3)(t+b_{13}F_1(t)+b_{23}F_2(t))}}{1 + \frac{q_3}{p_3} e^{-(p_3+q_3)(t+b_{13}F_1(t)+b_{23}F_2(t))}} \quad (13)$$

Case 4. This section discusses the diffusion of cross-regional model based on Kumar & Krishnan (2002) -- regional and regional discussions as to whether the impact will also be interactive. Since LCD monitor industry began to develop in Japan, entering the Japan market first and later the Taiwan and China markets, with China later than Taiwan, Japan is a lead country and Taiwan and China are lag countries. In the LCD monitor industry, because most of the creation of brands were in Japan and Taiwan, Japan and Taiwan would affect the adoption of brands in China, rather than China affecting Japan and Taiwan. Analysis of the relationship between the three regions' framework is shown in Figure 6:

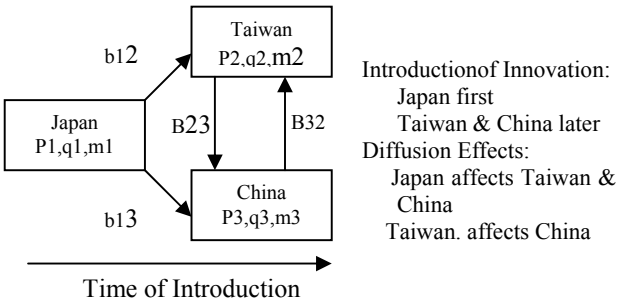


Figure 6. Lag-Lag and Simultaneous Effects for three regions

We have completed the description of the multinational framework, further designing the three regions' market formula, respectively, as follows:

$$N_1(t) = m_1 F_1(t) = m_1 \times \frac{1 - e^{-(p_1+q_1)t}}{1 + \frac{q_1}{p_1} e^{-(p_1+q_1)t}} \quad (14)$$

$$N_2(t) = m_2 F_2(t) = m_2 \times \frac{1 - e^{-(p_2+q_2)(t+b_{12}F_1(t))}}{1 + \frac{q_2}{p_2} e^{-(p_2+q_2)(t+b_{12}F_1(t))}} \quad (15)$$

$$N_3(t) = m_3 F_3(t) = m_3 \times \frac{1 - e^{-(p_3+q_3)(t+b_{13}F_1(t)+b_{23}F_2(t))}}{1 + \frac{q_3}{p_3} e^{-(p_3+q_3)(t+b_{13}F_1(t)+b_{23}F_2(t))}} \quad (16)$$

V. EMPIRICAL RESULTS

Results of the empirical demonstration of parameters estimation of the models are shown in Table 1:

TABLE I. EMPIRICAL RESULTS FOR THE PARAMETERS OF FINISHING

	U.S.A	Japan	Korea	Taiwan	China
Bass Model	*P*=0.00532	*P*=0.000431	*P*=0.007728	*P*=0.003853	*P*=0.0014
	q=0.059717	*q*=0.02524	*q*=0.05999	*q*=0.06049	*q*=0.064301
	m=1.9115E8	*m*=2.6559E9	*m*=2.0857E8	*m*=5.1308E8	*m*=4.5483E8
KK Model U.S.A. -Japan	*p*=0.005319	*p*=0.001543			
	q=0.059709	*q*=0.027438			
	m=1.912E8	*m*=7.3694E8			
		b_{12}=1.1E-7			
KK Model Japan -Korea		*p*=0.00083	*p*=0.007728		
		q=0.026007	*q*=0.059989		
		m=1.3765E9	*m*=2.0857E8		
			b_{12}=1.1E-7		
KK Model Japan -Korea - Taiwan		*p*=0.000488	*p*=0.007728	*p*=0.003852	
		q=0.025347	*q*=0.059989	*q*=0.060486	
		m=2.3463E9	*m*=2.0857E8	*m*=5.1319E8	
			b12=1.1E-8	*b13*=1.1E-8	
			b32=1.1E-8	*b23*=1.1E-8	
KK Model Japan - Taiwan -China		*p*=0.000372		*p*=0.003852	*p*=0.001478
		q=0.025128		*q*=0.060486	*q*=0.064552
		m=3.0816E9		*m*=5.1319E8	*m*=4.3045E8
				b12= 1.1E-8	*b13*= 1.109E-8
					b23= 1.1E-8

Results of empirical demonstrate know, whether it is Bass Models or KK models to imitate coefficient（q）are more than innovation coefficient（p）, In line with expectations. Because, that LCD industry, consumers' word-of-mouth effects are more than in accordance with external information and accepted the effects of innovation.

Four cases of KK Models, when the import of multinational parameters, although multinational parameters showed a very small, but it still makes imitating coefficient（q） more than innovation coefficient（p）, and this study found that the market potential of the law did not increase or decrease.

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

(1) U.S.A.：LCD products were the first invention of the U.S.A., but the development of the market, did not make good use, so that the diffusion of innovation had not been significant.

(2) Japan：Japan was the second to entry into the market, so coefficient of innovation lower than in other countries. However, we obtained the data can be found in the past two years in the imitate coefficient small than other countries, so we can find LCD

market in Japan has been gradually developed.

(3) Korea： Since LCD industries brand mostly from Japan and Korea, and Japan entry into the market earlier than Korea, innovation coefficient and imitate coefficient in Korea market are be higher.

(4) Taiwan：Following the optoelectronics industry is the development of the semiconductor industry strongly after the high-tech industry, a “two trillion, two star” one of the focal points. Therefore LCD industries rapid development, and now, have the first place in the global market share, so that, market potential （m）is highest.

(5) China：Because LCD late entry into the China market and China's rise when the economic situation (i.e. GDP), the imitate coefficient is higher than other countries, so more easily adopt the LCD.

VI. CONCLUSIONS

KK Models parameters are larger than Bass Models, although this study found that multinational parameters are significant, and the KK Models by other countries or regions affected, innovation coefficient, imitation coefficient and market potential almost larger than parameters of Bass Models.

The parameters results of Bass Models and KK Models, and innovation coefficients（p） are less than imitating coefficients（q）. In line with expectations also said the LCD industry's word-of-mouth effect among consumers effect greater than the impact of external effect. So if enterprises such as overestimation the effect of external information like an advertisement, or underestimate the word-of-mouth, the marketing strategy will be to develop resources on the error, not only the formation of waste, but also in turn affect the proliferation of new products. Strategy in the Enterprises should be actively majority of resources concentrated in upgrading product quality, functional diversification and further satisfy consumer’s feeling. Another mechanism can be set up after-sales service to enhance the goodwill of consumer’s products, and further create a better word-of-mouth effect.

Following are our recommendations for future research on this topic:

(1) The model assessment criteria, this study use the Adjusted R2 to make judgments. For ability to explain the better on model, future research direction can increase forecast assessment criteria example adopt Mean Absolute Percentage Error （MAPE） to strengthen the model assessment criteria.

(2) Dynamic competition in the market, the first place in the global market share will change on time. What to do to get the best model confirm is worth exploring.

(3) The duality of technology on countries, maybe change each other. In this study, innovation of technology on LCD had major breakthrough, in Taiwan. So the results of innovation coefficients and imitating coefficients may have different.

(4) The data in question must try to obtain from the most primitive to the recent data, the research results will better reflect the true market situation.

(5) On multinational diffusion model, in addition to KK model, are there better suited with goodness of fit? The proposals will continue to future research studies.

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