Empirical research on the diffusion of home appliances to the rural areas in china based on Bayesian estimated bass model

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Abstract

Quantitative research on the diffusion of Home Appliances to the Rural Areas in China is a very important topic both in theory and in application. Most of the research on diffusion focuses on the discussion and qualitative analysis of the policy. This paper expands the Bass model applications by leading an empirical research based on the history sales data of Home Appliances to the Rural Areas. The model has been estimated by both linear and nonlinear least squares method and Bayesian method separately, and predicts the maximum potential market in the end. This empirical research shows that Bayesian method performs best in predicting the diffusion of Home Appliances to the Rural Areas. Finally, the main factors influencing the policy implementation was analysed. It predicts the periodical sales and gives some suggestions to the government and enterprises accordingly.

Keywords: home appliances to the rural areas, diffusion of innovation, Bass model, Bayesian method

1 Introduction

Due to the financial crisis, Chinese government Appliances to the Rural Areas in China has boosted Chinese rural market. However, there is a series of unknown factors in the market: the prospect of the home appliances in the rural areas, the space of the rest of the market, the amount of the annually financial subsidy budget, the method of enterprises allocating resources, and so on. With these phenomena, there is a key factor, which is the forecast of the Home appliances market demand. It requires us to make precise predictions of the speed and scale of the diffusion of the home appliance products. The government, then, could make an accurate estimate of the governmental financial subsidy budget and the relevant formulation to guide the enterprises properly. The enterprises, then, could organize relevant production and development based on the estimation. For government, enterprises and the farmer consumers, it is clear that it has a practical significance to study the diffusion process of home appliance, predict the market capacity and the sales amount in each period and find important factors of the home appliance diffusion and the impact mechanism to the market.

On the other hand, Bass Model has been widely applied to the field of durable consumer goods and technology innovation diffusion. But there are several questions related to the bass model. Is it suitable to use it to analyse a variety of consumer durable goods, which are mixed together in the electrical home appliances especially with the effect of government subsidy? How does the brand effect with the mass media in the process of rural consumer accepting home appliances? What is the difference between the general consumer durable diffusion and innovation diffusion, and so on? Few literature studies could be found on this topic. This paper will focus on the diffusion study in the market of the home appliance products in the rural market. We propose the Bayesian parameter estimation method to the Bass Model of the application to compensate for the random error of the prediction due to the small sample size in the original studies.

This paper will analyse the pattern of the dynamic development and its potential power. On the one hand, it will expand the application of Bass Model. On the other hand, it could provide scientific evidence for the formulation of the governmental policy and the decision of the production and management of the enterprises.

2 Diffusion research on the home appliance products in the rural areas in China

The policy of home appliance products in the rural areas in china is an important move to thoroughly implement the government's proposal to expand the domestic demand. The detail of the policy is to start a country-wide project with an emphasis on the rural consumers in the R&D, production, and sale of the home appliances with fixed orientation, with government subsidy to certain levels. We call it a government supported "rural electrical and electronics propulsion project."

The home appliances diffusion is different to those of the other single products because it mixes various types of goods: television, refrigerator, air condition, microwave oven, washing machine, computer, mobile phone and so on. Although it is a mixture, it is clear that these consumer goods all belong to the durable ones. Consumers tend to be more careful when they make a purchasing decision. They

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shall always ask the opinions of the people around, and pay attention to the information on the television, broadcast, and newspapers and so on. These features are consistent with the ones of single products.

Fan Qiu Ju (2010) and Dunn Adam G (2012) proposed that the external influence is the promotion and implementation of national policy on home appliances. Until now, the U.S. subprime mortgage crisis has had a negative impact on China's home appliance exports. In order to mitigate the impact, the country was rolled out of pilot job of home appliances to the countryside which is directed by R&D, production, sales of designated home appliances for the rural consumer and capital subsidy given by the financial sector. After achieving excellent sales results, the second round of home appliances to countryside process was implemented fully and by stimulating domestic consumption and stimulating domestic demand would accomplish the goals of economic growth. With the coordination and propaganda of government and media, this policy has been fully understood by the farmers: they can buy products with reliable brand names with tangible subsidies. Then the farmers start to buy. This is the external factors of promoting the home appliance to countryside. These external factors promote innovators to proliferate to go to buy them firstly.

After obtaining satisfying outcomes, the farmers who have purchased the home appliances in the countryside would be willing to recommend this policy to more families to make a purchase. Their purchasing behaviour would inadvertently affect other farmers. Seeing the tangible benefits, other farmers will be stimulated to make their decisions to purchase. And they do. Wurui Juan (2010) proposed that this is the internal factors of home appliances to countryside – a process of the imitators following the innovators.

To sum up, home appliances in the countryside can be viewed as a consumer durable goods diffusion by Lu Dong Ning (2009). On one hand, it will promote the innovator in the farmer consumer groups to purchase appliance firstly under the influence of government, business, media and other external propaganda. On the other hand, as the key factor, the exemplary role and word of mouth will affect the amount and the rate of countryside home appliances' diffusion. The elements of diffusion and the factors of the Bass Model are very relevant in this sense. So we have chosen the Bass Model as countryside home appliance diffusion forecasting model to research the application of the Bass Model in the forecasting of countryside home appliances.

3 BASS model and its literature review

3.1 BASS BASIC MODEL

Bass Frank M (1969), D. Heckerman (1995) and Van den Bulte (2007) proposed that potential adopters are influenced by two factors: the mass media and word of mouth which are the two simple assumptions in Bass model. Innovators are influenced by the mass media,and imitators are influenced by the word of mouth. Bass's model is represented mathematically as:

$$h(t)=\frac{f(t)}{1-F(t)}=p+qF(t), \tag{1}$$

where: $h(t)$ is the chance of using new products, $f(t)$ is the time density function of adopter in the t period, $F(t)$ is the ratio of cumulative adopter between the totals, p represents the external influences (or Innovation coefficient or the influence of mass media), q represents the internal influence (or the imitation coefficient, or, word of mouth).

Then let us assume m be the maximum potentiality of the market or the maximum capacity of the market. The number of adopter $n(t)$ at t time is the formula two:

$$n(t)=mf(t). \tag{2}$$

The number of cumulative adopter is:

$$N(t)=mF(t). \tag{3}$$

By integrating Equation (2) we will get:

$$N(t)=m\left[\frac{1-e^{-(p+q)t}}{1+\frac{q}{p}e^{-(p+q)t}}\right]. \tag{4}$$

3.2 THE BAYESIAN PARAMETER ESTIMATION METHOD OF BASS MODEL

The accuracy of Bass Model parameter estimation is one of the key factors of the Diffusion Model. Because Bayesian parameter estimation method combines priori information with posteriori information, and it can effectively reduce random error because of few observations. This study selects Bayesian parameter estimation method as the basic method of the model, exploring the application of the Bayesian parameter estimation method in the Bass Model. In order to estimate the parameter m, p, and q in the Bass Model, we need to show the priori distribution of the parameter firstly, as follows:

Let $y(i)$ be the number of annual new adopters, and where $e_i \sim N(0,\sigma^2)$. Then

$$y(i)=m(F(t_i)-F(t_{i-1}))+e_i. \tag{5}$$

Assume as $\sigma=e^{\alpha}$ in Equation (5) and each parameter's prior distribution is:

$$P(p)=N(\mu_p,\nu_p),\ P(q)=N(\mu_q,\nu_q),$$
$$P(m)=N(\mu_m,\nu_m) \text{ and } P(\alpha)=N(\mu_\alpha,\nu_\alpha).$$

We will get the likelihood function:

$$\left(\frac{1}{\sqrt{2\pi e^{2\alpha}}}\right)^{n}\exp\left(-\frac{1}{2}\sum_{i=1}^{n}\left(\frac{y(i)-m\left(F\left(t_i\right)-F\left(t_{i-1}\right)\right)}{\exp(\alpha)}\right)^{2}\right), \quad (6)$$

where, n represents the period number of data.

Since the observation was produced from data, we can take the likelihood function as the conditional density function $P\left(y|p,q,m,\alpha\right)$ of that observation regarding $\theta=\{p,q,m,\alpha\}$.

Assume $h(\theta,y)$ (θ,y) as the joint density function of, θ, y. Then $h(\theta,y)=P\left(y|\theta\right)\pi\left(\theta\right)$, where $\pi(\theta)$ is a parameter. Then from the prior density function and the Bayesian equation, we can get:

$$h(\theta,y)=P\left(y|\theta\right)\pi\left(\theta\right)=P\left(\theta|y\right)m\left(y\right), \quad (7)$$

Where $P\left(\theta|y\right)$ is the posterior density function of parameters and $m\left(y\right)$ is the marginal density function of y where:

$$m\left(y\right)=\int_{\Theta}h(\theta,y)d\theta. \quad (8)$$

From Equation (7), we get the posterior density function:

$$P\left(\theta|y\right)=\frac{P\left(y|\theta\right)\pi\left(\theta\right)}{\int_{\Theta}P\left(y|\theta\right)\pi\left(\theta\right)d\theta}. \quad (9)$$

It is not easy to carry out the multi-dimensional integral that contains a number of unknown parameters. By pulling in MCMC method and Gibbs sampling, it generates some steady-state distribution as the Markov chain of the parameters' posteriori distribution. The average of all the iteration generated from steady Markov chain is the Bayesian estimation.

4 The experiments and analysis

4.1 THE SCREENING AND THE METRIC OF THE DATA SETS

According to the announcement regarding the information management system of the home appliances going to the countryside on the official website, we got the data of the national monthly sales volume of home appliances in the countryside from January 2009 to December 2009. Each data point represents the sales in all provinces of all kinds of household appliances, which are reported monthly.

This paper uses the MAE method to measure the preciseness of prediction, and the smaller the MAE the better. In the test set, the future points are $y=\left\{y_i\,|i=1,2,\ldots,n\right\}$, the real sales data set is $s=\left\{s_i\,|i=1,2,\ldots,n\right\}$, to each pair of "forecasted sales, real sales", to $\left\langle y_i,s_i\right\rangle$, there will be Equation:

$$MAE=\frac{\sum_{i\in N}(y_i-s_i)}{N}. \quad (10)$$

4.2 RESULTS OF THREE PARAMETERS ESTIMATION METHODS

TABLE 1 Estimation results of the linear least square method

	Estimation	***T* value**	***P* Value**
1	838088	1.484	0.171
x1	0.330	3.137	0.0119
x2	-6.10043E-09	-1.785	0.107
***R* squared**	0.763	***F* Ratio**	14.518
Adjusted *R* squared	0.710	***P* Value**	0.001

TABLE 2 Estimation results of the non-linear least square method

p	*0.00999058*	{0.002,0.0176}
q	0.293087	{0.067,0.519}

	DF	**Mean Squared**	***F* ratio**
Model	3	5.08494×10^{13}	47.918
Error	9	1.06117×10^{12}	

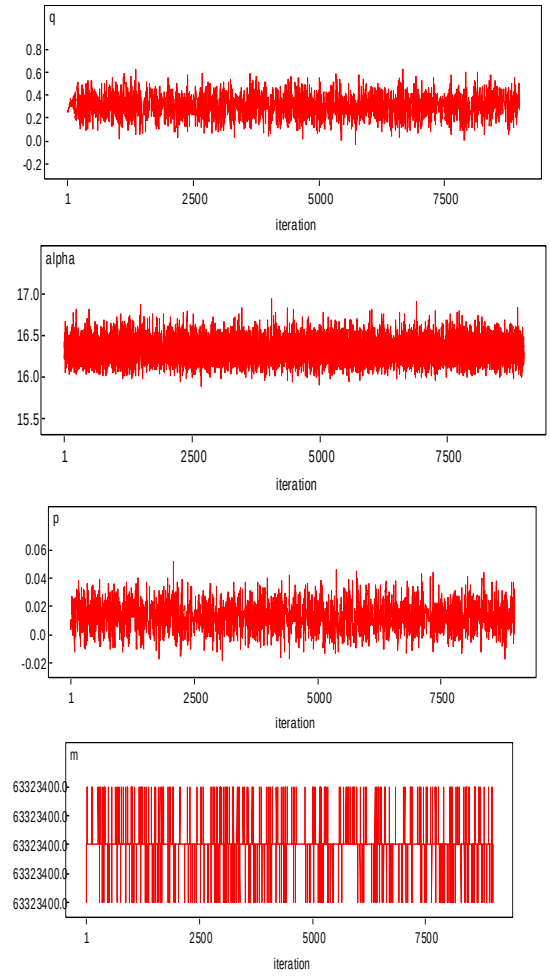

FIGURE 1 The convergence process of Bayesian parameters

Estimation results of least square method and non-linear least square method are presented in Table 1 and Table 2. Figure1 shows the convergence process of Bayesian parameters. The values given by the linear least square method are 56565700, 0.0148, 0.3451 correspondingly. The values given by the non-linear least square method are 56565700, 0.0148, 0.3451 correspondingly.

By the Bayesian parameters method we get the values of "*m*, *p*, *q*" are 63320000, 0.01293, 0.3044 correspondingly. Predicted values got by the three parameter estimation methods are presented in Table 3. We can see that the prediction results by the Bayesian parameters method are much better than those of the other two methods.

TABLE 3 Historical data and predictions (Unit: Tai)

Period	**Historical data**	**Forecast data**		
		Linear least square method	*Non-linear least square method*	*Bayesian Estimated Bass method*
1	338135	540330	649362	818727
2	875390	723418	835399	1054139
3	1484517	958139	1069371	1347749
4	1763304	1259188	1360065	1707577
5	2227725	1637793	1715493	2138392
6	2921096	2101288	2140993	2638363
7	4273119	2648019	2636329	3194646
8	3787773	3260276	3191807	778635
9	3159942	3896577	3783891	4342709
10	7046823	4486926	4371676	4821439
11	3871402	4937224	4896605	5140535
12	5930591	5148845	5288332	5234566
MAE		841149	805103	64040

5 Conclusion and future research

In summary, the growth mechanism of Bass model is applied to forecast National sales of home appliances in the countryside. And we can analyse and calculate its dynamic growth characteristics by the Bass model. Bayesian parameter estimation method has a good effect on the Bass model predictions. In addition, Because of declining growth rate of home appliances sales, diffusion of Home Appliances in the Rural Areas are dominated by the internal factors. According to the model, the government and the enterprise can estimate and predict the sales and market saturation time. Furthermore, it can make policy adjustment accordingly.

Ignoring the factors of the price of the home appliance product and the purchasing power of farmers, and so on, this paper is committed to investigating the impact of mass media and reputation on the policy of home appliances. In the future research, we will gradually add these variables in order to get deeper and more detailed investigation both quantitatively and qualitatively on the Diffusion of Home Appliances in the Rural Areas. On the other hand, the government continues to increase the varieties of home appliances in the countryside, and introduce a home appliance recycling policy. The future research will focus on the influence the policy on the diffusion of the appliances in the countryside.

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