Forecasting the Number of Subscribers of 3G Mobile Services in China

Based on Bass Diffusion Model

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Abstract: It is expected that 3G mobile services will be launched into the market in China. But it is hard to predict the demand of this new service. In this paper, Bass diffusion model and Norton-Bass model are adopted to make the prediction of number of 3G subscribers. Based on the regression analysis with actual data, the predicted results are acceptable. And finally, the paper points out that the price of 3G handsets and services, and backward compatibility are two factors influencing the diffusion of 3G greatly.

Key Words: Innovation Diffusion; Bass Model; 3G mobile services

1. Introduction

In 2004, there were some evidence that the 3G services began taking off around the world, as the 3G subscribers got a rapid growth in Japan, Korea and some European countries. For the telecommunication operators in China, it is the key period now for preparing the launch of 3G services into the market. The most important problem that all the operators are facing is to forecast the demand of 3G services in China, and consequently, to forecast the revenue and profits they can earn from 3G services. It is not easy to solve the problem, because 3G is a kind of new service and there is no enough historical data for forecasting. Although we can get some data of the development in some countries, comparative approaches are not quite applicable, considering the differences in economy, culture, and characteristics of market demand between countries. In fact, with the observation of the development of 3G services in some countries, we can find that the data showed totally different developing way, and it is hard to find the common experience directly from the short-term data.

As for new product forecasting, some innovation diffusion models (Bass, 1969; Lilien et al., 1992; Mahajan et al., 1993) can provide satisfactory results. These models typically use an S-shaped diffusion curve to model the cumulative sales up to time. In the past research, they have been validated empirically in many markets, and have been applied to telecommunication markets. Among them, the Bass diffusion model, developed by Professor Frank Bass in 1969, is one of the fundamental models to describe, and sometimes predict the purchases for consumer durable products.

In this paper, we use Bass diffusion model and Norton-Bass model to analyze the mobile
service market and try to forecast the number of subscribers of 3G services in China. And in addition to modeling the market, we will give the analysis on the key factors influencing the diffusion of 3G.

2. Bass diffusion model

The main concern of the innovation diffusion research is how innovations are adopted and why innovations are adopted at different rates. Rogers defines diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1995). The diffusion process involves the spread of a new idea from its source to potential adopters. According to Rogers (1995), mass medium, such as television, radio, newspapers, etc., is considered a more effective way to generate awareness of the innovation; whereas, interpersonal communication is considered more effective in influencing an individual's decision to adopt. Bass model and its extensions give a good description of the diffusion process.

2.1 Bass model

The Bass diffusion model on the adoption and diffusion of new products and technologies by Frank M. Bass and later extensions are used for market analysis and demand forecasting of new technologies. While Bass’s model yields an S-shaped cumulative-adoptions curve that has proven to provide excellent empirical fit for a wide range of new product.

The Bass model can be expressed as:

$$ f(t) = [p + qF(t)][1 - F(t)] $$  \hspace{1cm} (1)

where the random variable $t$ denotes the moment of adoption of a new product by an individual (adopter), $f(t)$ is the probability of adoption at time $t$ and $F(t)$ the cumulative distribution function.

The spread of a new method or concept in a market can be characterized by the *Bass formula*:

$$ N_t = N_{t-1} + p[m - N_{t-1}] + q \frac{N_{t-1}}{m} [m - N_{t-1}] $$  \hspace{1cm} (2)

where $N_t$= cumulative number of adopters by time after introduction.

The three parameters of the model are:

- $m$ = the market potential; the total number of people who will eventually use the product;
- $p$= the coefficient of innovation (external influence); the possibility that somebody who is not yet using the product will start using it because of mass media coverage or other external factors;
- $q$= the coefficient of imitation (internal influence); the possibility that somebody who is not yet using the product will start using it because of "word-of-mouth effect" or
other influence from those already using the product. 

The solution of the differential equation is

\[ F(t) = \frac{1 - e^{-(p+q)t}}{1 + \frac{q}{p} e^{-(p+q)t}} \] (3)

and

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

The standard Bass curve (with the average values of \( p \) and \( q \) of 0.03 and 0.38, respectively) looks like this:

![Figure 1 The standard Bass curve for the diffusion of innovations over time.](image)

2.2 Norton-Bass model

Norton-Bass model is the first model of sales of multiple generations of products, which is an extension of the Bass model. It deals with sales of successive generations of products in those cases where adopters continue buying the product at a constant rate. The Norton-Bass model has been shown to provide very good fits to sales data for each product generation for several product categories.

The Norton-Bass model equations for three generations are

\[ S_1(t) = F(t_1) m_1 [1 - F(t_2)] \]
\[ S_2(t) = F(t_2) [m_2 + F(t_1) m_1] [1 - F(t_3)] \] (5)
\[ S_3(t) = F(t_3) \{m_3 + F(t_2) [m_2 + F(t_1) m_1] \} \]

where \( S_g(t) \) is sales of generation \( g \) at time \( t \), \( t_g \) is the time since the introduction of generation \( g \), \( m_g \) represents the incremental market potential for generation \( g \) and \( F(t_g) \) is the cumulative adoption function of the Bass model at time \( t_g \).

In the model, sales of generation 1 will be \( m_1 F(t_1) \) until generation 2 arrives and then it will be this quantity minus what generation 2 draws, and \( m_g \) is a parameter which can be estimated. The \( F \) functions do not have generational features because Norton and Bass found that for several product categories, the parameters \( p \) and \( q \) were the same through generations. A more general version of the model explored by Norton (1986), designates generational subscripts for the \( F \) functions with \( p \) and \( q \) varying by generation.
3. Modeling the mobile telecommunication services market

3.1 The development of mobile service in China

There are the most mobile subscribers in the world in China. But the really rapid growth began in the late of 1990s, and 3G services have not been launched. The number of subscribers of 1G (analog system) and 2G (GSM and CDMA) are listed in table 1.

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<tbody>
<tr>
<td>1G</td>
<td>0.7</td>
<td>3.2</td>
<td>9.8</td>
<td>18</td>
<td>48</td>
<td>177</td>
<td>638</td>
<td>1568</td>
<td>3535</td>
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<tr>
<td>2G</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>0.7</td>
<td>3.2</td>
<td>9.8</td>
<td>18</td>
<td>48</td>
<td>177</td>
<td>638</td>
<td>1568</td>
<td>3629</td>
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</thead>
<tbody>
<tr>
<td>1G</td>
<td>5205</td>
<td>6387</td>
<td>6243</td>
<td>4755</td>
<td>3962</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2G</td>
<td>1648</td>
<td>6846</td>
<td>17255</td>
<td>38255</td>
<td>81298</td>
<td>144812</td>
<td>206616</td>
<td>268693</td>
<td>334824</td>
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<td>Total</td>
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<td>13233</td>
<td>23498</td>
<td>43010</td>
<td>85260</td>
<td>144812</td>
<td>206616</td>
<td>268693</td>
<td>334824</td>
</tr>
</tbody>
</table>

Data: http://www.mii.gov.cn/mii/hyzw/tjxx.html

3.2 Bass model fit to the total number of mobile subscribers

Fitting Bass model to the total number of mobile subscribers requires that three parameters be estimated: \( m \), \( p \) and \( q \).

The first parameter, \( m \), means the total number of people who will eventually use mobile service. According to the characteristics of current mobile subscribers, the people who use mobile services are usually at the age of 15 to 65, and have the purchasing power. Because telecommunication service has becoming the requisite for the human lives, it is acceptable to assume that all the people with those characteristics will adopt mobile service eventually. According to the basic statistics on China population census (2000), among Chinese people, about 70% are at the age of 15 to 64, and 16% are still suffering from poverty. Then based on the rates listed above, with the total population of China 1.3 billion, we can estimate the upper limit of the market potential as:

\[
m = 1.3 \times 10^9 \times 70\% \times (1 - 16\%) \approx 7.6 \times 10^8
\]

Considering more factors, including education and health, we make an adjustment and estimate that

\[
m = 7 \times 10^8 \text{ (thousand)}.
\]

The equation (4) can be expressed as

\[
S(t) = \frac{m[1 - e^{-at}]}{1 + be^{-at}}
\]

by specifying

\[
a = p + q, \tag{7}
\]

and

\[
b = q / p. \tag{8}
\]
For the year of 1987, we specify \( t=1 \), for 1988, \( t=2 \), and so on. Using non linear regression procedure of SPSS, we can have the estimate of \( a \) and \( b \): 

\[ a = 0.48685, \quad b = 6423.36466 \quad (R \text{ squared}=0.99394). \]

According to the equation (7) and equation (8), the parameter \( p \) and \( q \) can be calculated out:

\[ p = 7.57819 \times 10^{-5} \quad \text{and} \quad q = 0.48677. \]

Figure 2 shows the Bass model compared to the observations and indicates that the model provides a good fit to the data.

![Bass model fit to total number of mobile subscribers](image)

With the model, the number of mobile subscribers in China in the following three years can be predicted as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of mobile subscribers</td>
<td>469885</td>
<td>550954</td>
<td>616296</td>
</tr>
</tbody>
</table>

### 3.3 Norton-Bass model fit to the number of subscribers of the two generations

According to the set of equations (5), we have a model for two generations:

\[
S_1(t) = F(t_1)m_1[1 - F(t_2)] \\
S_2(t) = F(t_2)[m_2 + F(t_1)m_1]
\]

(9)

Fitting the model to two generations requires that 4 parameters be estimated: \( m_1 \), \( m_2 \), and \( p \) and \( q \).

Since 3G service has not been launched, we can also get the estimate that \( m_2 = 7 \times 10^5 \) (thousand).

With \( F(t) = [1 - e^{-(p+q)t}] / [1 + (q/p)e^{-(p+q)t}] \), and by specifying

\[ a = p + q, \]

...
and \( b = q / p \),

then we have

\[
S_1(t) = m_1 \left[ (1 - e^{-at}) \right] \left[ (1 + b) e^{-at} \right] / \left[ (1 + (1 + be^{-at})) \right]  \\
S_2(t) = [m_2 + m_1 (1 - e^{-at})] / [1 + be^{-at}]  \\
\]

For the year of 1987, we specify \( t=1 \), for 1988, \( t=2 \), and so on. Similarly using non linear regression procedure of SPSS, we can have the estimate of \( m_1, a \) and \( b \):

\[
m_1 = 7728, \quad a = 0.47653, \quad and \quad b = 118.28694.  \\
\]

According to the equation (7) and equation (8), the parameter \( p \) and \( q \) can be calculated out:

\[
p = 0.003995 \quad and \quad q = 0.47254  \\
\]

Figure 3 shows the model fits to the two generations and R-squares for each generation.

![Figure 3: Norton-Bass model fit to two generations mobile subscribers](image)

4. Forecasting the number of subscribers of 3G service based on the models

If 3G service is launched by the end of 2005, the parameter \( m_2, p \) and \( q \) may change. Then we should use the set of equations (5) for three generations. The result of regression analysis in Part 3 provides references for re-estimating these parameters.

The total market potential can still be set as 0.7 billion subscribers. Given the condition that the 4G services will not be launched in the near future, we can give the estimate for \( m_3 \):

\[
m_3 = 7 \times 10^7 \quad \text{(thousand)}.  \\
\]

Then for 2G, the market potential \( m_2 \) should be re-estimated. Now we can use the forecasting results give in part 3.2. And considering the development data of 3G services in Japan for reference, we can find that the subscriber number of 2G began falling down two years after the launch of 3G (shown as Figure 4). Then it is reasonable to assume that the
market potential of 2G will not exceed the predicted number of subscribers in 2007 (listed in table 2). Based on that, we give the estimate for $m_2$ as:

$$m_2 = 6 \times 10^5 \text{ (thousand)}.$$
With the established model, the subscribers of 3G in the following five years are given in table 3.

Table 3  The predicted number of 3G subscribers in China (unit: thousand)

<table>
<thead>
<tr>
<th>Year</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of 3G subscribers</td>
<td>4255</td>
<td>11673</td>
<td>24049</td>
<td>44036</td>
<td>75443</td>
</tr>
</tbody>
</table>

5. Key factors affecting the diffusion of 3G service

In Bass model and Norton-Bass model, only the total market potential and the communication factors are considered directly. But obviously, marketing efforts from operators can affect the diffusion rate by influencing the external and internal communication coefficient: \( p \) and \( q \). Two key factors should be emphasized specially.

The first factor is the price of 3G mobile handsets and services. Most people would not upgrade if it costs a lot. To adopt 3G services, a mobile subscriber has to change his handset first, and may pay more for mobile services. Now the average price of 3G handsets is about 50% higher than that of 2G or 2.5G handsets. It results in that only top customers who do not care the higher cost would upgrade to 3G. At the same time, if the prices of 3G services are much higher, the diffusion rate will remain low in a long period, because the current 2G services can fulfill the mobile communication demand for most people. Providing large subsidies to customers for purchasing handsets is a useful way for mobile operators to accelerate the diffusion of 3G services.

The second factor is backward compatibility. If the mobile operators can upgrade their networks smoothly, they will provide good compatibility for customers, which is one of the characteristics influencing the adoption rates. In Japan, backward compatibility is the key reason for KDDI’s higher subscriber growth compared with NTT DoCoMo (as shown in Figure 4). With relatively small differences in technology between its 2G and 3G networks, KDDI adopted the policy to upgrade all customers into the 3G system, once they change handsets (yearly or so).

If people can upgrade from 2G to 3G easily and conveniently without much additional costs, the number of 2G subscribers will fall down very quickly as 3G diffuses. It is determined by the policies of marketing and technology evolution routes taken by mobile
operators. Once 3G services are launched into the market, it is necessary for operators to accelerate the diffusion as quickly as possible. No matter how wonderful the 3G services will be, operators can not get profits without a large scale of subscribers.

6. Conclusions

In this paper, we use Bass model and Norton-Bass model to fit the diffusion process of mobile services and get acceptable results. It shows that diffusion model can be used as a good tool to forecast the demand of new telecommunication services. And according to the estimate of parameters, we can find that in the diffusion of telecommunication services, the coefficient of imitation (greater than the average value 0.38) is more important than the coefficient of innovation (much less than the average value 0.03).

For the future, many factors, especially the activities of operators, can not be predicted. The prices of 3G handsets and services and backward compatibility are the key factors influencing the diffusion speed of 3G services.

References
