Retail sales forecast analysis of general hospitals in Daejeon, Korea, using the Huff model

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Accepted 26 September, 2011

This paper seeks to develop a sales estimation model to forecast the demand for general hospitals in small and medium-sized cities. We focus on deriving the parameter λ in the Huff model, which is used in sales forecasting. When opening new hospitals in cities, actual sales can be calculated on the basis of a demand forecast. Currently, many researchers in Korea use the Huff model to estimate the sales of retail stores, but we employ it to analyze the impact of such factors as hospital size and the proximity of hospitals to consumers. We look at in what ways and to what extent these factors affect the λ calculation. From past experiments, we know that the parameter varies according to city size. By making comparisons with existing studies on large cities, we verify that consumers in small and medium-sized cities are less sensitive to travel time. Meanwhile, we determine λ to be 0.1 in the case of such cities, implying that hospital size has a greater influence on consumers than travel time does. According to existing studies, this figure is 0.38 for small and medium-sized cities and more than 1 for large cities.

Key words: Huff model, general hospitals, forecast analysis.

INTRODUCTION

This paper relies on the Huff model, which has formerly been used in retailing, to estimate the demand for services in general hospitals. On the basis of existing studies, we assess whether such estimation is possible and calculate the value of λ in the Huff model. In Korea and Japan, distribution companies have a unique buying system, the so-called Tukjung-meip (with Korean). It is a unique dealing system in Korea; the system let salesman pay the bill for the only sold products and return the suppliers, not letting them pay whole prices of supplied products. Korean distribution experts claim that this system allows companies to keep up with competitors such as Wal-Mart in the United States or Carrefour in Europe. In the case of large-scale retailers in Korea, Tukjung-meip accounts for 70 to 80% of the outsourcing of merchandising and marketing activities to vendors by large-scale retailers. The latter engage in this process in order to cut the costs incurred by marketing an individual brand or product. In comparison, the alternative Jikmeip (with Korean) system accounts for only 5% of such activities. Jikmeip is a kind of dealing method between distributor and supplier. The distributors purchased products of suppliers first and then sales directly for customers. In other words, system characteristics such as position and size are the most important factors, and for this reason, the Huff model is the most accurate sales estimation theory.

Korean customers tend to favour general hospitals over primary or secondary care facilities, despite the higher
Table 1. The Classification of medical institution for Huff model applying.

<table>
<thead>
<tr>
<th>Category</th>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical institution</td>
<td>Tertiary hospitals</td>
<td>General hospitals (more than 100 hospital beds) and hospitals (more than 30 hospital beds) are medical institutions that provide medical treatment for inpatients, whereas clinics mainly serve outpatients</td>
</tr>
<tr>
<td></td>
<td>General hospitals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hospitals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clinics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nursing homes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Over 1000 People</td>
<td></td>
</tr>
<tr>
<td></td>
<td>500 - 999</td>
<td>General hospitals</td>
</tr>
<tr>
<td></td>
<td>300 - 499</td>
<td>Hospitals</td>
</tr>
<tr>
<td></td>
<td>100 - 299</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No Beds</td>
<td></td>
</tr>
</tbody>
</table>

costs of the former. General hospitals are often preferred for their cutting-edge facilities and wide range of services. Since 1989, the Korean government has implemented a medical delivery system consisting of clinics/health centres (primary care facilities), clinics/nursing hospitals/general hospitals (secondary care facilities), and general specialty medical institutions (tertiary hospitals). Contrary to expectation, however, the policy failed to differentiate between the medical functions of each class. The function of specialty hospitals has overlapped with not only general hospitals but also with clinics (Lee, 2004). The classification of medical institutions under the Huff model is shown in Table 1 (You et al., 2007). Judging from Korea’s actual medical system, sales estimation prior to the opening of a general hospital holds great significance. We selected Daejeon, a medium-sized city, as the focus of our inquiry, since it is an independent trading area that offers a clear contrast to the subjects of existing studies.

PREVIOUS STUDY AND PROPOSED MODEL

Past studies related to sales and demand estimation demonstrates the importance of location. When it comes to retail stores, the choice of a store’s location is one of the most important decisions that retailers make (Craig et al., 1984; Kotler, 1994). In selecting the right location, return on investment is the crucial decision criterion (Krause-Traudes et al., 2008). Therefore, retailers must evaluate the potential sales of a new store. Three approaches are employed for this purpose: (1) the Huff gravity model; (2) regression analysis; and (3) the analog model (Levy and Weitz, 2007). In this study, we focus on the Huff gravity model, which is widely used in retailing practice (Hernandez and Bennison, 2000) because of (1) its ease of use (Park et al., 2006; Lv et al., 2008; Ahn et al., 2009) and (2) the accuracy of its predictions (Drezner and Dressner, 2002), even though the two-variable specification is too parsimonious for policy purposes (Gautschi, 1981). Several empirical studies (Huff and Blue, 1966; Haines et al., 1972) support the usefulness of the Huff model in predicting the market share of shopping centres (Craig et al., 1984).

In this model, the probability that customer \(i\) shops at location \(j\) depends upon two factors: the size of the store and the time it takes to travel to the store (Levy and Weitz, 2007). The larger the store, the greater is the probability of shopping, while the greater the travel time or distance, the lower the probability. The mathematical formula is as follows (Huff, 1964):

\[
P_{ij} = \left( \frac{S_j}{T_{ij}} \right) \left( \sum \frac{S_j}{T_{ij}} \right)^{-1}
\]

Here, \(P_{ij}\) is the probability of a consumer at location \(i\) travelling to use facility \(j\). \(S_j\) is the size of facility \(j\). \(T_{ij}\) is the travel time or distance from location \(i\) to facility \(j\), and \(\lambda\) is an empirically estimated parameter that reflects the effect of travel time on various kinds of shopping trips. In the case of retail stores, the expected number of consumers at location \(i\) who shop at a particular shopping centre \(j\) equals the number of consumers at \(i\) multiplied by the probability that a consumer at \(i\) will select \(j\) for shopping (Huff, 1964). Here, \(\lambda\) reflects the relative influence between store size and travel time (Park et al., 2006; Levy and Weitz, 2007; Kim and Youn, 2010; Kim et al., 2011). When \(\lambda\) is 1, the probability of a consumer shopping at a particular shopping centre is not influenced by store size and/or travel time. If \(\lambda\) is larger than 1, travel time has a greater influence (Kim and Youn, 2010). We can assume that the same relation applies to hospitals. The value of \(\lambda\) is also influenced by consumer tendencies to travel to a particular shopping centre (Levy and Weitz, 2007). Travel time, or distance, is more important for convenience goods than shopping goods because consumers are less willing to travel a longer distance to buy a bottle of milk than a pair of new shoes. The calculation of \(\lambda\) has been discussed in previous studies (Huff and Blue, 1966; Haines et al., 1972). However, Japan and Korea have been using a fixed value of 2 for \(\lambda\).
Table 2. Size of and travel time to general hospitals.

<table>
<thead>
<tr>
<th>General hospitals</th>
<th>General hospital size (N beds)</th>
<th>I (min)</th>
<th>II (min)</th>
<th>III (min)</th>
<th>IV (min)</th>
<th>V (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>418</td>
<td>21</td>
<td>4</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>B</td>
<td>988</td>
<td>24</td>
<td>3</td>
<td>7</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>C</td>
<td>530</td>
<td>21</td>
<td>3</td>
<td>7</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>D</td>
<td>736</td>
<td>27</td>
<td>14</td>
<td>17</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>E</td>
<td>218</td>
<td>23</td>
<td>3</td>
<td>9</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>F</td>
<td>318</td>
<td>3</td>
<td>24</td>
<td>23</td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td>G</td>
<td>450</td>
<td>16</td>
<td>14</td>
<td>13</td>
<td>14</td>
<td>19</td>
</tr>
</tbody>
</table>

*Travel time means community i to general hospitals j.

Table 3. Probability of a consumer at a given point of origin i travelling to a particular medical centre j.

<table>
<thead>
<tr>
<th>General hospital</th>
<th>Probability of communities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I (%)</td>
</tr>
<tr>
<td>A</td>
<td>11.3</td>
</tr>
<tr>
<td>B</td>
<td>26.2</td>
</tr>
<tr>
<td>C</td>
<td>14.3</td>
</tr>
<tr>
<td>D</td>
<td>19.3</td>
</tr>
<tr>
<td>E</td>
<td>5.8</td>
</tr>
<tr>
<td>F</td>
<td>10.6</td>
</tr>
<tr>
<td>G</td>
<td>12.5</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

(Youn, 1997). The value of $\lambda$ was set at 2 in by earlier researchers, who have calculated the market share of retail stores in big cities using the Huff model (Yim and Lee, 2000).

According the studies on big cities in Japan and Korea employing this model, distance has a greater influence over store size on shopping probability. The average error rate was 1.6% when $\lambda$ equaled 2 (Yim and Lee, 2000). However, $\lambda$ was derived to be 0.38 with an absolute error rate of 1.13% for a medium-sized city in Korea (Kim and Youn, 2010). This signifies that consumers in a medium-sized city are more sensitive to the size of facilities than they are to distance. Using existing studies as a reference, this paper estimates sales by calculating the market share of hospitals.

DISCUSSION

This study assumes that differences exist between the hospital usage of consumers living in medium-sized cities and their shopping behaviour at retail stores. Specifically, they are less likely to visit nearby hospitals. This assumption leads in turn to another: consumers living in medium-sized cities are more sensitive to hospital size than to distance. Consumers are more attracted to large hospitals because of their varied of medical services and their high accessibility in medium-sized cities. For the purpose of comparison; we have selected a study on retail stores conducted in the city of Daejeon, the focus of our study (Kim and Youn, 2010). Daejeon, a small city compared to Seoul, had 439, 312 households and 7 general hospitals in 2003. As shown in Table 2, we divided Daejeon into five communities and estimated general hospital sales based on secondary data, including hospital size, travel time, and distance.

We estimated the probability of a consumer at location i travelling to a particular medical centre j as follows:

1. When $\lambda = 2$, Table 3 presents the probability of a consumer at location i travelling to a particular medical centre j when $\lambda$ has this value. For example, the probability of community 1 residents using medical centre A is 11.3%. For community 2, community 3, community 4 and community 5, this Figure 1 stands at 11.9, 11.5, 12.0, and 12.2%, respectively. For example, among the 71, 968 households of community 1, a total of 51,768 are likely to use medical centre A. Table 4 shows that medical centre A, with a market share of 11.8%, is used by this number of households. By community, the number
of households using medical centre A is 8,107 for community 1; 10,293 for community 2; 9,693 for community 3; 17,529 for community 4; and 6,146 for community 5. This method was applied to estimate the market share of each hospital. We then compared the estimated market share with the actual market share, or actual sales. Table 5 shows the estimated market share, actual market share, and error rate. The error rate is calculated as follows:
Table 6. Error rates depending on different $\lambda$s.

<table>
<thead>
<tr>
<th>Lambda ($\lambda$)</th>
<th>Average error rate (%)</th>
<th>Sum of error rates (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>3.77</td>
<td>30.1</td>
</tr>
<tr>
<td>0.03</td>
<td>3.76</td>
<td>30.09</td>
</tr>
<tr>
<td>0.05</td>
<td>3.76</td>
<td>30.04</td>
</tr>
<tr>
<td>0.07</td>
<td>3.75</td>
<td>30.00</td>
</tr>
<tr>
<td>0.09</td>
<td>3.75</td>
<td>30.00</td>
</tr>
<tr>
<td>0.10</td>
<td>3.74</td>
<td>29.90</td>
</tr>
<tr>
<td>0.11</td>
<td>3.75</td>
<td>30.00</td>
</tr>
<tr>
<td>0.20</td>
<td>3.85</td>
<td>30.80</td>
</tr>
<tr>
<td>0.30</td>
<td>3.96</td>
<td>31.70</td>
</tr>
<tr>
<td>0.40</td>
<td>4.06</td>
<td>32.50</td>
</tr>
<tr>
<td>0.50</td>
<td>4.18</td>
<td>33.40</td>
</tr>
<tr>
<td>0.70</td>
<td>4.40</td>
<td>35.20</td>
</tr>
<tr>
<td>1.00</td>
<td>4.73</td>
<td>37.80</td>
</tr>
<tr>
<td>1.50</td>
<td>5.14</td>
<td>41.10</td>
</tr>
<tr>
<td>2.00</td>
<td>5.39</td>
<td>43.10</td>
</tr>
<tr>
<td>2.50</td>
<td>5.63</td>
<td>45.0</td>
</tr>
<tr>
<td>3.00</td>
<td>5.86</td>
<td>46.90</td>
</tr>
<tr>
<td>3.50</td>
<td>5.98</td>
<td>47.80</td>
</tr>
<tr>
<td>4.00</td>
<td>6.00</td>
<td>48.00</td>
</tr>
</tbody>
</table>

Error = Expected market share – actual market share.

2. Estimation of $\lambda$: This study derived the parameter $\lambda$ by following the steps below. After setting the value of $\lambda$ at between 0.1 and 4, we calculated the probability of a consumer at location i travelling to a particular medical centre j, and the estimated sales of each medical centre. Next, we retrieved the error rate by comparing the estimated market share with the actual market share. This process was repeated to obtain an optimal $\lambda$ with minimal error.

Step 1: Calculating the probability of a consumer at location i travelling to a particular medical centre j while varying $\lambda$. This was accomplished in the same manner as that shown in Table 3.

Step 2: Calculating the estimated market share. Using the probability obtained from fixed values of $\lambda$, we calculated the number of households at each medical centre and the estimated market share, as in Table 4.

Step 3: Calculating the error rate. As in Table 5, we compared the estimated market share with the actual market share based on actual data and calculated the error rate.

Step 4: Obtaining the value of $\lambda$ for minimal error. Table 6 shows the error rate for each value of $\lambda$. Here, the rate of average error was calculated as follows: Average error rate = sum of error rates/number of medical centres. By comparing the estimated market share with the actual market share, the distribution of error rates for different $\lambda$ values can be represented as a graph. This is shown in Figure 2.

In this study, we estimated hospital sales based on the estimated market share and then verified our results by making comparisons with the actual market share, or actual sales. In this process, we found that the error rate was minimal when $\lambda$ was set to 0.10. The average error rate in this study was 3.74%. When estimating sales for a hospital located in Daejeon, the minimum error rate fell below 3.74% when $\lambda$ was fixed at 0.10. This implies that consumers in Daejeon are more likely to travel to larger hospitals, which they assume to provide better medical services, regardless of distance.

Conclusion

Past Korean studies have only applied the Huff model to retail stores. We have shown it applicability to medical centres. We investigated the way in which city size affects the parameter $\lambda$ in the case of hospitals. In particular, we looked at two representative studies of retail stores in Korea. First, Yim and Lee (2000) showed that travel time has a greater influence than store size when $\lambda$ is larger than 1 for retail stores in big cities. In addition, a $\lambda$ of 0.38 is given in another study of retail stores conducted in our study city, Daejeon (Kim and Youn, 2010). By comparing our findings with these two studies, we find that consumers are less sensitive to travel time (or more sensitive to hospital size) to medical
centres than to retail stores in medium-sized cities. We obtain a smaller $\lambda$ value of 0.10, when compared to the 0.38 obtained for retail stores, indicating that the size of the medical centre has a greater influence than travel time. This result proves that Daejeon’s citizens are more interested in hospital size than in travel time when seeking medical services.

However, the constraints on this study should be noted. First, our results cannot be directly applied to other medium-sized cities since the parameter $\lambda$ was derived specifically for Daejeon. This study still serves as a starting point for any estimation of hospital sales that takes into account city size as a factor. Our results may be compared with future calculations of $\lambda$ for hospitals in cities other than Daejeon. Second, serial analysis was not possible since the data on Daejeon were collected at a single point in time. Nonetheless, this study holds great significance as $\lambda$ may be longitudinally expanded.

REFERENCES


