Healthcare demand forecasting: methods and application for Brazil

Cristina Guimarães Rodrigues  
(University of São Paulo)  
Mônica Viegas Andrade  
Bernardo Lanza Queiroz  
Carla Jorge Machado  
(Cedeplar/UFMG)

9 -11 November 2011  
Rio de Janeiro
1 - Goals

• 1 – General
  - To show how the literature forecast health services utilization

• 2 – Specific
  - To apply the Lee-Carter method in the field of health services research to forecast hospital admission rates in Minas Gerais state / Brazil from 2011 to 2020.
  - To compare the performance of the Lee-Carter method with the traditional methods of forecasting health services utilization based on simple trend extrapolation (deterministic method).
2 - Why forecast healthcare demand?

• To anticipate resources requirements:

- budgetary resources,
- Infrastructure and supply of health services
2 - Associated factors of health services utilization

- Epidemiologic profile
- Demographic dynamic
- Characteristics of health care system

Healthcare utilization
2 - Uncertainty of the future rates?
3 – Basic equation of forecasting health services utilization

\[ nU_x^t = \sum_x nUR_x^t * nP_x^t \]

- \( nU_x^t \) = utilization (in units) in time t
- \( nUR_x^t \) = utilization rates by age group x to x+n in time t
- \( nP_x^t \) = population by age group x to x+n in time t
3.1 – How the traditional methods deal with $n UR^t_x$

$$n U^t_x = \sum_x n UR^t_x \ast n P^t_x$$

1) **Pure demographic effect** - $n UR^t_x$ is fixed over time (Finlayson et al, 2004; Schulz et al, 2004; Tate et al, 2004; Strunk et al, 2006)

2) **Deterministic** – trends in $n UR^t_x$ are considered, by simple trend extrapolation, i.e. fixed annual variation (Evans et al, 2001; Finlayson et al, 2004)
4 – How we deal with $nUR_x^t$

Stochastic approach (Lee-Carter, 1992)

$\ln(nu_{x,t}) = n\alpha + nxk_t + n\varepsilon_{x,t}$

\[
\hat{u} = \begin{pmatrix}
\hat{u}_{0,1996} & \hat{u}_{0,1997} & \hat{u}_{0,1998} & \hat{u}_{0,1999} & \ldots & \hat{u}_{0,2010} \\
\hat{u}_{1,1996} & \hat{u}_{1,1997} & \hat{u}_{1,1998} & \hat{u}_{1,1999} & \ldots & \hat{u}_{1,2010} \\
\hat{u}_{2,1996} & \hat{u}_{2,1997} & \hat{u}_{2,1998} & \hat{u}_{2,1999} & \ldots & \hat{u}_{2,2010} \\
\vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\
\hat{u}_{80,1996} & \hat{u}_{80,1997} & \hat{u}_{80,1998} & \hat{u}_{80,1999} & \ldots & \hat{u}_{80,2010} \\
\end{pmatrix}
\]

$k_t = c + k_{t-1} + u_t$

ARIMA (0,1,0)
4.1 – Comparison with deterministic method

\[ nUR_x^z = nUR_x^i \* \left[ 1 + nW_x \* (t^z - t^i) \right] \]

\[ \frac{1}{2} \ln\left( \frac{1-nU_x^z}{nU_x^i} \right) = \frac{1}{2} \ln\left( \frac{1-nU_x^i}{nU_x^i} \right) \* \left[ 1 + nW_x \* (t^z - t^i) \right] \]

- \( W_x \) = average annual growth rate of admission rate in the period between \( t \) and \( t + n \) by age group, where the period \( i + z \) comprises the time between the beginning and end of the series observed.
5 – Database

• **Database:** Sistema de Informações Hospitalares do Sistema Único de Saúde – SIH/SUS (Hospital System Information from Unified Health System)

• **Historical time series:** from 1996 to 2010 - period delimited by Chow Test (Greene, 2000)

• **Period of forecasting:** from 2011 to 2020

• **Retrospective forecasting:** data from 1996 to 2005 to forecast from 2006 until 2010
Trends in total admission rates

- **Minas Gerais**
- **Brazil**

Date:
- 1993
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010

Standardized admission rate
6 – The fitted model

Actual admission rates
Estimated admission rates

Source: SIH/SUS and PNAD/IBGE – 1996 to 2010
6 – The fitted model

Source: SIH/SUS and PNAD/IBGE – 1996 to 2010
6 – The fitted model

<table>
<thead>
<tr>
<th>Age group</th>
<th>Proportion of variance</th>
<th>Age group</th>
<th>Proportion of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 4</td>
<td>92.0%</td>
<td>45 – 49</td>
<td>97.9%</td>
</tr>
<tr>
<td>5 – 9</td>
<td>95.4%</td>
<td>50 - 54</td>
<td>95.4%</td>
</tr>
<tr>
<td>10 – 14</td>
<td>85.6%</td>
<td>55 – 59</td>
<td>94.5%</td>
</tr>
<tr>
<td>15 – 19</td>
<td>85.7%</td>
<td>60 – 64</td>
<td>96.4%</td>
</tr>
<tr>
<td>20 – 24</td>
<td>91.0%</td>
<td>65 – 69</td>
<td>94.9%</td>
</tr>
<tr>
<td>25 - 29</td>
<td>93.5%</td>
<td>70 – 74</td>
<td>92.7%</td>
</tr>
<tr>
<td>30 – 34</td>
<td>98.1%</td>
<td>75 – 79</td>
<td>91.8%</td>
</tr>
<tr>
<td>35 – 39</td>
<td>91.3%</td>
<td>80 and over</td>
<td>61.9%</td>
</tr>
<tr>
<td>40 – 44</td>
<td>96.5%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VARIÂNCIA GLOBAL = 91,5%
Figure 2: Actual admission rates and forecasts – Minas Gerais, 1996 to 2020

Source: SIH/SUS and PNAD/IBGE – 1996 to 2010
Figure 3: Actual admission rates (2010) and forecasts (2020) by age groups – Minas Gerais

Source: SIH/SUS and PNAD/IBGE – 1996 to 2010
Figure 4: Actual admission rates and forecasts by age groups – Minas Gerais, 2010

Source: SIH/SUS and PNAD/IBGE – 1996 to 2010
Figure 4: Actual admission rates and forecasts – Minas Gerais, 2010

Source: SIH/SUS and PNAD/IBGE – 1996 to 2010
## Backward forecasting – 2006 to 2010
### Total Admission Rates

<table>
<thead>
<tr>
<th>Ano</th>
<th>Actual admission rate</th>
<th>LC forecast: median</th>
<th>LC forecast: 95% wide probability bounds</th>
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<th>Deterministic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rate</td>
<td>Variation</td>
<td>Rate</td>
<td>Variation</td>
</tr>
<tr>
<td>2006</td>
<td>5,86</td>
<td>5,79</td>
<td>-1,11</td>
<td>5,65</td>
<td>-3,57</td>
</tr>
<tr>
<td>2007</td>
<td>5,60</td>
<td>5,60</td>
<td>0,11</td>
<td>5,40</td>
<td>-3,55</td>
</tr>
<tr>
<td>2008</td>
<td>5,39</td>
<td>5,42</td>
<td>0,54</td>
<td>5,17</td>
<td>-4,12</td>
</tr>
<tr>
<td>2009</td>
<td>5,34</td>
<td>5,25</td>
<td>-1,69</td>
<td>4,96</td>
<td>-7,13</td>
</tr>
<tr>
<td>2010</td>
<td>5,46</td>
<td>5,08</td>
<td>-6,94</td>
<td>4,76</td>
<td>-12,86</td>
</tr>
</tbody>
</table>

Source: SIH/SUS and PNAD/IBGE - 2006 to 2010
5 – Concluding remarks

- The main contribution of this article is to quantify uncertainty in health services utilization,
- The Lee-Carter method can be applied to other variables besides mortality,
- The best fitted model was LC method (median estimates), but the performance may be different if different period of data is used,
- Despite the shortcoming to use a short time-series to estimate future health care utilization rates, the procedures seem to work well with the data.
Forecasting based on trends from 1996 to 2007

- Centered smoothing averages in these age groups:
  - 10 to 14
  - 15 to 19
  - 75 to 79
  - 80 and over
6 – The fitted model (1996 to 2007)

Source: SIH/SUS and PNAD/IBGE – 1996 to 2010
### 6 – The fitted model

#### Proportion of variance explained by the model

<table>
<thead>
<tr>
<th>Age group</th>
<th>Proportion of variance before smoothing</th>
<th>Proportion of variance after smoothing</th>
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</thead>
<tbody>
<tr>
<td>0 – 4</td>
<td>95,5</td>
<td>95,2</td>
</tr>
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<td>93,9</td>
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<td>82,4</td>
<td>85,8</td>
</tr>
<tr>
<td>20 – 24</td>
<td>90,3</td>
<td>90,1</td>
</tr>
<tr>
<td>25 – 29</td>
<td>92,0</td>
<td>91,8</td>
</tr>
<tr>
<td>30 – 34</td>
<td>96,4</td>
<td>96,7</td>
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<td>99,9</td>
</tr>
<tr>
<td>80 and over</td>
<td>49,3</td>
<td>87,6</td>
</tr>
<tr>
<td>Global variance</td>
<td>89,1</td>
<td>93,3</td>
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Source: SIH/SUS and PNAD/IBGE – 1996 to 2010
Backward forecasting – 2003 to 2007
(based on trends from 1996 to 2002)

Total Admission Rates

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<td></td>
<td>Rate</td>
<td>Variation</td>
<td>Rate</td>
<td>Variation</td>
</tr>
<tr>
<td>2003</td>
<td>6,49</td>
<td>6,48</td>
<td>-0,03</td>
<td>6,27</td>
<td>-3,31</td>
</tr>
<tr>
<td>2004</td>
<td>6,16</td>
<td>6,29</td>
<td>2,17</td>
<td>5,99</td>
<td>-2,81</td>
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<tr>
<td>2005</td>
<td>6,00</td>
<td>6,11</td>
<td>1,75</td>
<td>5,73</td>
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<tr>
<td>2006</td>
<td>5,87</td>
<td>5,93</td>
<td>1,11</td>
<td>5,49</td>
<td>-6,47</td>
</tr>
<tr>
<td>2007</td>
<td>5,61</td>
<td>5,76</td>
<td>2,70</td>
<td>5,26</td>
<td>-6,19</td>
</tr>
</tbody>
</table>

Source: SIH/SUS and National Household Sample Survey - 2003 to 2007