A Bed Constraint?
Hospital Occupancy Rates and Readmission Episodes

Luís Filipe

Nova Health Care Initiative

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Motivation

Portuguese Hospitals tend to be very crowded. Sometimes, people associate perceived lower treatment standards with hospital occupancy rates. Let's see if that is true.

High occupancy rates may lead to:

- Operational Failures
- Early Discharges

And cause negative outcomes such as:

- Readmissions
- Deaths

This paper tries to assess whether occupancy rates are associated with readmission episodes possibly driven by early discharges.
Objective

Are occupancy rates associated with the likelihood of readmission?

1. Check how occupancy rates at discharge are related with readmissions
2. Determine if the effect is constant across age groups
3. Evaluate the relation between length of stay and occupancy
Data

Data provided by the Portuguese Central Administration of the Health System (ACSS) containing yearly collected DRGs’ (Diagnosis Related Groups) for all discharges in the Portuguese hospital centers.

The number of beds are publicly available in the institutional site of ACSS for each hospital in each month.

Note: The dataset provides an individual identification code that allows the researcher to check readmission episodes.

The sub-sample:

* Years of 2014, 2015 and 2016 (No December) and a total of 41 hospitals.

* Only inpatients whose DRG belongs to the 7 more prevalent Major Categories of Diagnosis in the sample: the respiratory system (18.79%), circulatory system (18.22%), musculoskeletal system (16.45%), digestive system (15.47%), nervous system (11.53%), urinary system (10.66%) and hepatobiliary system (8.88%).
### Data - Readmissions

- **Counted at the index admission**

- **Two approaches:**
  - Standard: 30 days
  - Conservative: 30 days and same MDC

- **Averages 8% in the Standard and 4% in the Conservative**

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**Diagram:**

- Readmission Rate over time from January 2013 to December 2015.

- The graph shows fluctuations in the readmission rate, with peaks in December 2013 and December 2014.
Data - Occupancy

- Number of patients hospitalized in each day dividing by the number of beds
- Occupancy is counted at discharge (or in relation to discharge day)
- Averages 97.31% (overestimated)
Methodology

The baseline model:

\[ y_{iht} = \alpha + \beta \text{Occupancy}_{iht} + \gamma X_{it} + \theta \text{DRG}_{it} + \tau_y \times \tau_m \times \tau_w \times \tau_h + \varepsilon_{iht} \]  

(1)

Where:

- \( y_{iht} \) corresponds to a readmission being generated after individual \( i \) is discharged in hospital \( h \) at day \( t \).
- \( \text{Occupancy}_{iht} \) is the occupancy rate in the day of discharge (or days just prior to discharge).
- \( X \) contains a set of control variables such as age, gender, number of procedures.
- \( \text{DRG} \) are DRG fixed effects interacted with severity level.
- \( \tau_y \times \tau_m \times \tau_w \times \tau_h \) are an interaction between year/month/week and hospital fixed effects.

\[ \implies \text{The paper uses a Linear Probability Model} \]
## Results: Occupancy at Discharge and Readmission Likelihood

<table>
<thead>
<tr>
<th>Dependent variable: Readmission Episodes</th>
<th>Standard</th>
<th>Conservative</th>
<th>Standard</th>
<th>Conservative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupancy at Discharge</td>
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<tr>
<td></td>
<td>(0.008)</td>
<td>(0.005)</td>
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</tr>
<tr>
<td>Turnover Rate</td>
<td>0.053***</td>
<td>0.025***</td>
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<tr>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
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<tr>
<td>Occupancy Rate Variation</td>
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<td>-0.107***</td>
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<tr>
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<td>(0.005)</td>
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<tr>
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*Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, Standard errors in parentheses.*
Are discharges decided within the same day?
## Results: Occupancy One Day Before Discharge and Readmission Likelihood

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<tr>
<th>Dependent variable: Readmission Episodes</th>
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<th>Standard</th>
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<tr>
<td>Occupancy Rate Variation t-1</td>
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<td>0.006***</td>
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Should the effect be linear?
## Results: Readmission and Occupancy Intervals

<table>
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<tr>
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<th>Conservative t-1</th>
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<tr>
<td>Occupancy Rate $&gt; 110%$ t-1</td>
<td>0.014***</td>
<td>0.008***</td>
<td>0.019***</td>
<td>0.010***</td>
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<td>(0.002)</td>
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<td>(0.001)</td>
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<tr>
<td>Occupancy Rate [105%, 110%] t-1</td>
<td>0.009***</td>
<td>0.006***</td>
<td>0.012***</td>
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<td>(0.002)</td>
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<td>(0.001)</td>
</tr>
<tr>
<td>Occupancy Rate [100%, 105%] t-1</td>
<td>0.007***</td>
<td>0.005***</td>
<td>0.010***</td>
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<td>(0.002)</td>
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<tr>
<td>Occupancy Rate [95%, 100%] t-1</td>
<td>0.006***</td>
<td>0.004***</td>
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<tr>
<td>Occupancy Rate [90%, 95%] t-1</td>
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<td>0.003**</td>
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<td>0.003**</td>
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<tr>
<td>Occupancy Rate [85%, 90%] t-1</td>
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<td>0.029***</td>
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Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, Standard errors in parentheses.
Does it affect all patients in the same way?
Results: Occupancy and Readmissions by Age Groups

Figure: Coefficients of Occupancy Rates on Readmissions

- Occupancy Coefficient
- Variation Coefficient \(t-1\)

Luís Filipe (Nova Health Care Initiative)
A Bed Constraint?
June 12, 2019
Since we are talking about early discharges, what about length of stay?
### Results: Occupancy and Length of Stay by Thresholds

**Dependent variable: Readmission**

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>Conservative</th>
<th>Standard</th>
<th>Conservative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupancy t-1 &amp; Max Limit Length</td>
<td>0.010***</td>
<td>0.004***</td>
<td>(0.002)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Occupancy t-1 &amp; Superior Limit Length</td>
<td>0.008***</td>
<td>0.002</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Occupancy t-1 &amp; Above Expected Length</td>
<td>-0.055***</td>
<td>-0.029***</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Occupancy t-1 &amp; Below Expected Length</td>
<td>0.035***</td>
<td>0.020***</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Occupancy t-1 &amp; Min Limit Length</td>
<td>-0.037***</td>
<td>-0.016***</td>
<td>(0.003)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Turnover Rate t-1</td>
<td>0.021***</td>
<td>0.011***</td>
<td>(0.002)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Variation t-1 &amp; Max Limit Length</td>
<td>0.151**</td>
<td>0.069*</td>
<td>(0.049)</td>
<td>(0.029)</td>
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<tr>
<td>Variation t-1 &amp; Superior Limit Length</td>
<td>0.046</td>
<td>0.056*</td>
<td>(0.038)</td>
<td>(0.025)</td>
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<tr>
<td>Variation t-1 &amp; Above Expected Length</td>
<td>-0.143***</td>
<td>-0.106***</td>
<td>(0.038)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>Variation t-1 &amp; Below Expected Length</td>
<td>0.150***</td>
<td>0.106***</td>
<td>(0.037)</td>
<td>(0.027)</td>
</tr>
<tr>
<td>Variation t-1 &amp; Min Limit Length</td>
<td>0.116*</td>
<td>0.081*</td>
<td>(0.056)</td>
<td>(0.038)</td>
</tr>
<tr>
<td>Male</td>
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<td>0.006***</td>
<td>0.009***</td>
<td>0.006***</td>
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<tr>
<td>Number of Procedures</td>
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<td>0.000***</td>
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<tr>
<td>Age Groups</td>
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</tbody>
</table>

*Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, Standard errors in parentheses.*
Results: Occupancy and Length of Stay Thresholds by Age Groups

Figure: Coefficients of Occupancy Rates on Length of Stay

- Maximum length interval
- Superior length interval
- Above average length interval
- Below average length interval
- Minimum length interval
Conclusion

- Occupancy rates prior to discharge are associated with higher probability of readmission
- The effects differ across age groups, with the elderly being more affected
- Higher occupancy rates and being discharged with lower than expected length of stay is associated with readmissions.
- Again, older people are the ones suffering

* Occupancy rates and readmission episodes appear to be linked though early discharges of older people
Thank you for your time!
Other Results
### Other Results: Occupancy Two Days Before Discharge and Readmission Likelihood

**Dependent variable: Readmission Episodes**

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>Conservative</th>
<th>Standard</th>
<th>Conservative</th>
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<tbody>
<tr>
<td>Occupancy Two Days Before Discharge</td>
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<td>(0.005)</td>
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<td>(0.007)</td>
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<td>Turnover Rate t-2</td>
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<tr>
<td>Occupancy Rate Variation t-2</td>
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<td>0.006***</td>
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<td>(0.000)</td>
<td>(0.000)</td>
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<tr>
<td>Male</td>
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*Notes: *p < 0.05, **p < 0.01, ***p < 0.001, Standard errors in parentheses.*
Other Results: Occupancy Three Days Before Discharge and Readmission Likelihood

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<tr>
<th>Dependent variable: Readmission Episodes</th>
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<th>Standard</th>
<th>Conservative</th>
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<td>0.008***</td>
<td>0.006***</td>
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</tr>
<tr>
<td>Number of Procedures</td>
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Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, Standard errors in parentheses.
## Other Results - Occupancy by Months

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<th>Standard Variation t-1</th>
<th>Conservative Variation t-1</th>
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<td><strong>January</strong></td>
<td>0.038***</td>
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<td>0.116***</td>
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<tr>
<td></td>
<td>(0.007)</td>
<td>(0.007)</td>
<td>(0.024)</td>
<td>(0.017)</td>
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<td><strong>February</strong></td>
<td>0.042*</td>
<td>0.053***</td>
<td>0.067</td>
<td>0.026</td>
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<td></td>
<td>(0.021)</td>
<td>(0.006)</td>
<td>(0.034)</td>
<td>(0.028)</td>
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<td><strong>March</strong></td>
<td>0.017</td>
<td>-0.001</td>
<td>0.100***</td>
<td>0.031*</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.007)</td>
<td>(0.018)</td>
<td>(0.015)</td>
</tr>
<tr>
<td><strong>April</strong></td>
<td>0.057***</td>
<td>0.039*</td>
<td>0.093***</td>
<td>0.032***</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.020)</td>
<td>(0.026)</td>
<td>(0.008)</td>
</tr>
<tr>
<td><strong>May</strong></td>
<td>0.032</td>
<td>0.018</td>
<td>0.077***</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.017)</td>
<td>(0.021)</td>
<td>(0.018)</td>
</tr>
<tr>
<td><strong>June</strong></td>
<td>0.053**</td>
<td>0.035</td>
<td>0.087***</td>
<td>0.032*</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.019)</td>
<td>(0.016)</td>
<td>(0.014)</td>
</tr>
<tr>
<td><strong>July</strong></td>
<td>0.065***</td>
<td>0.046***</td>
<td>0.015</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.012)</td>
<td>(0.030)</td>
<td>(0.015)</td>
</tr>
<tr>
<td><strong>August</strong></td>
<td>0.026</td>
<td>-0.002</td>
<td>0.080**</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.011)</td>
<td>(0.031)</td>
<td>(0.015)</td>
</tr>
<tr>
<td><strong>September</strong></td>
<td>0.012</td>
<td>0.010</td>
<td>0.008</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.010)</td>
<td>(0.013)</td>
<td>(0.010)</td>
</tr>
<tr>
<td><strong>October</strong></td>
<td>0.013</td>
<td>0.003</td>
<td>0.022</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.014)</td>
<td>(0.017)</td>
<td>(0.011)</td>
</tr>
<tr>
<td><strong>November</strong></td>
<td>0.026</td>
<td>0.022</td>
<td>0.060***</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.013)</td>
<td>(0.015)</td>
<td>(0.016)</td>
</tr>
</tbody>
</table>

**Age Groups**  | ✓ ✓ ✓ ✓  
**Year x Month x Week x Hospital FE** | ✓ ✓ ✓ ✓  
**DRG x Severity FE** | ✓ ✓ ✓ ✓  
**Observations** | 1,687,348 1,687,348 1,687,348 1,687,348

*Notes: * p < 0.05, **p < 0.01, ***p < 0.001, Standard errors in parentheses.*
## Other Results - Occupancy by Day of the Week

<table>
<thead>
<tr>
<th>Day</th>
<th>Standard Occupancy t-1</th>
<th>Conservative Occupancy t-1</th>
<th>Standard Variation t-1</th>
<th>Conservative Variation t-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>0.015</td>
<td>0.011</td>
<td>0.021</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.007)</td>
<td>(0.026)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>Tuesday</td>
<td>0.032***</td>
<td>0.025***</td>
<td>-0.021</td>
<td>-0.033*</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.007)</td>
<td>(0.023)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Wednesday</td>
<td>0.009</td>
<td>0.004</td>
<td>0.010</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.005)</td>
<td>(0.020)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Thursday</td>
<td>0.024**</td>
<td>0.016*</td>
<td>-0.023</td>
<td>-0.028</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.007)</td>
<td>(0.025)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>Friday</td>
<td>0.023*</td>
<td>0.008</td>
<td>-0.008</td>
<td>-0.011</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.006)</td>
<td>(0.021)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>Saturday</td>
<td>0.014</td>
<td>0.009</td>
<td>-0.006</td>
<td>-0.008</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.008)</td>
<td>(0.021)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>Sunday</td>
<td>0.021</td>
<td>0.009</td>
<td>-0.020</td>
<td>-0.009</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.011)</td>
<td>(0.045)</td>
<td>(0.034)</td>
</tr>
</tbody>
</table>

### Notes:
- * $p < 0.05$
- ** $p < 0.01$
- *** $p < 0.001$
- Standard errors in parentheses.

Age Groups: ✓ ✓ ✓ ✓

Year x Month x Week x Hospital FE: ✓ ✓ ✓ ✓

DRG x Severity FE: ✓ ✓ ✓ ✓

Observations: 1,687,348 1,687,348 1,687,348 1,687,348
### Other Results: Occupancy by MCD

<table>
<thead>
<tr>
<th>Dependent variable: Readmission</th>
<th>Standard Occupancy t-1</th>
<th>Conservative Occupancy t-1</th>
<th>Standard Variation t-1</th>
<th>Conservative Variation t-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nervous</td>
<td>0.065**</td>
<td>0.017</td>
<td>0.046</td>
<td>-0.008</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.012)</td>
<td>(0.026)</td>
<td>(0.013)</td>
</tr>
<tr>
<td>Respiratory</td>
<td>0.171***</td>
<td>0.095***</td>
<td>0.178***</td>
<td>0.088***</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.017)</td>
<td>(0.022)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>Circulatory</td>
<td>0.070***</td>
<td>0.053***</td>
<td>0.069***</td>
<td>0.027*</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.012)</td>
<td>(0.017)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>Digestive</td>
<td>0.030</td>
<td>0.007</td>
<td>0.039**</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.008)</td>
<td>(0.015)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>Hepatic</td>
<td>0.098***</td>
<td>0.069**</td>
<td>0.150***</td>
<td>0.106***</td>
</tr>
<tr>
<td></td>
<td>(0.027)</td>
<td>(0.023)</td>
<td>(0.030)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>0.011</td>
<td>-0.001</td>
<td>0.008</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.006)</td>
<td>(0.017)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>Urinary</td>
<td>0.049*</td>
<td>-0.001</td>
<td>0.048</td>
<td>0.016</td>
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<td>(0.024)</td>
<td>(0.020)</td>
<td>(0.034)</td>
<td>(0.024)</td>
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<tr>
<td>Age Groups</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Year x Month x Week x Hospital FE</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>DRG x Severity FE</td>
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<td>✓</td>
<td>✓</td>
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<tr>
<td>Observations</td>
<td>1,687,348</td>
<td>1,687,348</td>
<td>1,687,348</td>
<td>1,687,348</td>
</tr>
</tbody>
</table>

**Notes:** * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, Standard errors in parentheses.
### Other Results: Occupancy and Length of Stay

<table>
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<tr>
<th>Dependent variable: Length of Stay</th>
<th>Column (1)</th>
<th>Column (2)</th>
<th>Column (3)</th>
<th>Column (4)</th>
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</thead>
<tbody>
<tr>
<td>Occupancy at Discharge</td>
<td>4.813***</td>
<td>8.087***</td>
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<tr>
<td>(0.363)</td>
<td>(0.321)</td>
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</tr>
<tr>
<td>Occupancy One Day Before Discharge</td>
<td></td>
<td></td>
<td>1.221***</td>
<td>1.093***</td>
</tr>
<tr>
<td>(0.245)</td>
<td>(0.242)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Turnover Rate</td>
<td>7.112***</td>
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</tr>
<tr>
<td>(0.408)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Occupancy Rate Variation</td>
<td>-0.370</td>
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<tr>
<td>(0.312)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turnover Rate t-1</td>
<td></td>
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<td>9.422***</td>
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<td>(0.445)</td>
<td></td>
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<td>9.533***</td>
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<td>(0.466)</td>
</tr>
<tr>
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<td>0.049*</td>
<td>0.048*</td>
<td>0.048*</td>
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<tr>
<td>(0.020)</td>
<td>(0.020)</td>
<td>(0.020)</td>
<td>(0.020)</td>
<td></td>
</tr>
<tr>
<td>Number of Procedures</td>
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<td>0.962***</td>
<td>0.963***</td>
<td>0.963***</td>
</tr>
<tr>
<td>(0.006)</td>
<td>(0.006)</td>
<td>(0.006)</td>
<td>(0.006)</td>
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<tr>
<td>Age Groups</td>
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<td>✓</td>
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<td>✓</td>
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<tr>
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<tr>
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<td>✓</td>
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<td>1,687,348</td>
<td>1,687,348</td>
<td>1,687,348</td>
</tr>
</tbody>
</table>

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors in parentheses.
Other Results: Occupancy and Length of Stay by Age Groups

Figure: Coefficients of Occupancy Rates on Length of Stay

- Age
- Coefficients of Occupancy
- Confidence Intervals

Luís Filipe (Nova Health Care Initiative)

A Bed Constraint?

June 12, 2019