Identifying strategies for increasing efficiencies in bus transport in India by estimating a cost function

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Motivation

• Rapid economic development in India → increasing mobility demand → Rising share of personal vehicles
  – Lower share of public transport
  – Higher energy consumption, emissions, noise, waste, etc.
  – Social & political impact

• Strategy: increase share of public bus transport in passenger transport

• Need for investments → financial viability
  – Cost savings → Optimal organization of production to obtain savings
    • Economies of Density and Scale
    • Impact of management form of firms on the cost structure
Density and Scale Economies

- Large number of ‘small’ firms
  - Smallest firm: 32 buses
- Some very large firms
  - Largest firm: 19000+ buses

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Density and Scale Economies

• Hedonic approach:
  – Specify cost function of aggregated output measure and hedonic measures of output mix \( C = f(w, \varphi(y, N)) \) and \( \varphi(y, N) = y \phi(N) \)
  – More generally, \( C = f(w, y, N) \)

• Implication:

\[
C = f(w, y) \quad \Rightarrow \quad ES(w, y) = \frac{1}{e_{cy}(w, y)}
\]

\[
ED(w, y, N) = \frac{1}{e_{cy}(w, y, N)}
\]

\[
C = f(w, y, N) \quad \Rightarrow \quad ES(w, y, N) = \frac{1}{e_{cy}(w, y, N) + e_{cN}(w, y, N)}
\]
Cost characteristics of public bus transit in

\[ C = f \left( pkm, P_i, P_f, P_k, t, LF, NL, AR_i, MG_i \right) \]

- Specification issues
  - Dummy variables for Management Structure, Area of Operation (urban, mixed, hilly)
  - Translog, normalized at median. Homogeneity imposed with capital price
- Dataset
  - All public bus companies in India
  - NL data available only for 8 years, Model with NL allows distinction between Density and Scale
  - Unbalanced panel: 51 firms over 8 years

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Estimation methods

- **Fixed Effects**
  
  \[ C_{it} = \alpha_0 + X_{it} \alpha_1 + \nu_i + \varepsilon_{it} \]
  
  \[ \varepsilon_{it} \sim \left( 0, \sigma^2_\varepsilon \right) \]

- **Random Effects**
  
  \[ C_{it} = \alpha_0 + X_{it} \alpha_1 + \nu_i + \varepsilon_{it} \]
  
  \[ \nu_i \sim \left( 0, \sigma^2_\nu \right) \mid \varepsilon_{it} \sim \left( 0, \sigma^2_\varepsilon \right) \]

  \[ \text{Cov}(\nu_i + \varepsilon_{it}, \nu_j + \varepsilon_{jt}) = \begin{cases} 
  \sigma^2_\nu + \sigma^2_\varepsilon & \text{if } i = j \text{ and } s = t \\
  \sigma^2_\varepsilon & \text{if } i \neq j \text{ or } s \neq t 
  \end{cases} \]

- **SUR**
  
  \[ C_{it} = \alpha_0 + X_{it} \alpha_1 + \varepsilon_{it} \]
  
  \[ S_{it} = \beta_0 + x_{it} \beta_1 + \varepsilon'_{it} \]

...
### Environmental variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
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<tbody>
<tr>
<td>Load factor</td>
<td>$-0.36^{**}$</td>
</tr>
<tr>
<td>Network Length</td>
<td>$0.13^{***}$</td>
</tr>
<tr>
<td>Mixed operations</td>
<td>$-0.59^{***}$</td>
</tr>
<tr>
<td>Hilly Areas</td>
<td>$-1.32^{***}$</td>
</tr>
<tr>
<td>Company</td>
<td>$0.61^*$</td>
</tr>
<tr>
<td>Municipal Undertaking</td>
<td>$0.62^*$</td>
</tr>
<tr>
<td>Corporation</td>
<td>$0.88^{***}$</td>
</tr>
</tbody>
</table>

- Combining rural & urban operations leads to lower costs
- Impact of management structure is ambiguous
  - Road transport corporations are most expensive

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Economies of Density and Scale

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<tr>
<th>Economies of Scale</th>
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<tbody>
<tr>
<td>Small</td>
<td>2.087</td>
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<tr>
<td>Medium</td>
<td>1.450</td>
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<tr>
<td>Large</td>
<td>1.155</td>
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<tr>
<td>Very large</td>
<td>0.953</td>
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</table>

<table>
<thead>
<tr>
<th>Economies of Density</th>
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</thead>
<tbody>
<tr>
<td>Small</td>
<td>9.583</td>
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<tr>
<td>Medium</td>
<td>2.150</td>
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<tr>
<td>Large</td>
<td>1.293</td>
</tr>
<tr>
<td>Very large</td>
<td>0.842</td>
</tr>
</tbody>
</table>

- Significant Scale Economies for median firms
  - Fall as output increases
- After including NL, 30% of the largest firms show Economies
  - Density & Scale
- Potential for cost reduction from mergers

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Policy directions

For India:

• Potential for cost savings from mergers
  – Especially small firms
  – Firms operating in neighbouring areas
  – Combine rural and urban operations
• Side by side competition on the same network not useful for cost savings

In general:

• Research on the best production structure, don’t go by ‘best practice’ approach.
• If it’s a monopoly, regulate; don’t force competition in the market.