Chapter 32. Application to Economics: Cost Allocation in India

• Problem and Prior Modeling
• Determining Cost
• Alternative Solutions and Comparison
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- *Investment Planning in the Electric Power Industry, A Mixed-Integer Programming Approach, with Application to Southern India*
- Professor of Economics, Faculty of Arts and Sciences, New York University
- Teaches economics of energy and the environment
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Nature of the Problem

• Four Indian regions bear a huge capital outlay for new power generators to supply needed capacity
• The regions are Mysore (now called Karnataka), Kerala, Andhra Pradesh, Tamil Nadu
• Each State Electricity Board plans for self-sufficiency, resulting in inefficient use of joint assets
• There are alternative arrangements possible, resulting in various costs and benefits according to who cooperates
• As policy analysts we want to deliver a fair, equitable and efficient arrangement
How to Evaluate the Costs and Benefits of Cooperation?

Mixed Integer Linear Programming

Calculate the optimum investment and routing of power under various scenarios of cooperation

Decision variables are routing as well as location of the physical plant

Computer optimization makes the vast number of possibilities a tractable problem

Example from (Turkay, 1998)
Cost Calculations

<table>
<thead>
<tr>
<th>Coalition structure</th>
<th>$T$</th>
<th>$A$</th>
<th>$K$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>${T} {A} {K}$</td>
<td>533</td>
<td>187</td>
<td>86</td>
<td>806</td>
</tr>
<tr>
<td>${T, K} {A}$</td>
<td>260</td>
<td>187</td>
<td>242</td>
<td>689</td>
</tr>
<tr>
<td>${A, K} {T}$</td>
<td>533</td>
<td>48</td>
<td>148</td>
<td>729</td>
</tr>
<tr>
<td>${T, A} {K}$</td>
<td>552</td>
<td>147</td>
<td>86</td>
<td>785</td>
</tr>
<tr>
<td>${T, A, K}$</td>
<td>301</td>
<td>101</td>
<td>251</td>
<td>653</td>
</tr>
</tbody>
</table>

$T = $ Tamil Nadu $\quad A = $ Andhra Pradesh $\quad K = $ Kerala-Mysore

Units are 10 million rupees, value in 1974.

Table from Game Theory and Strategy (Straffin 1993) p.209
The Savings Game

\[
\begin{align*}
v(T) &= v(A) = v(K) = 0 \\
v(TK) &= 533 + 86 - 502 = 117 \\
v(AK) &= 187 + 86 - 196 = 77 \\
v(TA) &= 533 + 187 - 699 = 21 \\
v(TAK) &= 533 + 187 + 86 - 653 = 153
\end{align*}
\]

Table adapted from Game Theory and Strategy (Straffin 1993) p.210
A Variety of Cooperative Concepts. Which to Choose?

• Why Use the **Core**? We believe that we should pursue a solution in the best interests of all parties.

• And, because we want a single value solution:
  • Why Use the **Shapley Value**? We hope to mediate the situation based on principles of fairness.
  • Why Use the **Nucleolus**? We hope to maximize general satisfaction with the solution.
  • Why Use the **Gately Point**? We know that Kerala-Mysore should be placated for their strategic assets.
Strategic Assets: Hydroelectric Power in Kerala-Mysore

Nagarjuna Sagar Dam in Andhra Pradesh. Picture by Sumanthk (public domain).
Finding the Core

Players A and T can secure at least 21 from cooperation. Thus K can secure no more than 132.

Diagram adapted from Game Theory and Strategy (Straffin 1993) p.210
Solving for the Nucleolus

Diagram adapted from Game Theory and Strategy (Straffin 1993) p.210
Graphical Comparison of Solutions

This is the cost game.

In recognition of the strategic advantages of Kerala-Mysore we ask them to pay less.

Otherwise, quite comparable results!

If we were to use other non-cooperative measures, the solution would be way outside of the core.

Diagram adapted from Game Theory and Strategy (Straffin 1993) p.210
Gately’s More Recent Work

- OPEC expansion and consequent oil pricing
- Any OPEC nations able to expand export will have strong incentives to do so
- OPEC may not be able to maintain its level of export
- Reasonable assumptions about price responsiveness and non-OPEC supply means that real oil prices will not be sustainably much higher (2006)
- OPEC under investing in capacity for its own sake, and that of the world.