A Framework for Estimating Economies of Agglomeration and Supply Chain Network Effects in Maritime Clusters

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Scope of the Paper

- Economic Clusters
- Economies of Agglomeration
- Supply Chain Network Effects
- Port Clusters
- Framework for Estimating Effects
  - Gravity Model
  - Production Function
- Application to Panama Canal
Clusters of Economic Activity

- Michael Porter – “…. geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition.”

- Clusters Affect Productivity
  - Better access to a pool of employees and suppliers
  - Access to specialized market, technical, and competitive information
  - Complementarities - linkages among cluster members that results in a whole greater than the sum of its parts.
Problems with Cluster Theory

- Identification of the Geographic Boundaries of the Cluster
- I-O Tables Do Not Capture
  - Firm rivalry and collaboration,
  - Marshallian externalities
  - Knowledge spillovers
- Location Quotients Added to I-O Table to Capture Effects
Economies of Agglomeration

- Clusters Can Result in Economies of Agglomeration
- Measures of Agglomerative Economies:
  - Population Size, Population Density, Travel Time
  - Urban Size
- Not Useful for Maritime Clusters
Network Effects

- Competitive Advantage is Obtained from Value Created by a Network of Firms
- Performance of Network Has Multiple Attributes:
  - Cost Reduction
  - Reliability, Responsiveness, Flexibility
  - Improving Quality, Meeting Schedule Requirements, Accessing New Technologies
Economies of Agglomeration - Result from Cluster Economies

Economies of Scope from 3rd Party Logistics Providers (3PLs)

Economies of Density - Result in Lower Costs through Greater Volume of Activity and Make Specialists Feasible

Network Effects -
- Cost Reduction
- Reliability, Responsiveness, Flexibility
- Improving Quality, Meeting Schedule Requirements, Accessing New Technologies
- Customer Service Benefits
Measuring Effects in Port Clusters

- Effects Intertwined
- Separation of Effects Difficult if Not Impossible

Approach:
- Two Models of Effects – Gravity and Production Function
- Indices of Economies and Network Effects
Gravity Model Formulation

\[ T_{ij} = \frac{G \cdot A_i \cdot A_j}{d_{ij}^2} \]

- \( T_{ij} \) = number of trips between places i and j, respectively
- \( A_i \) = measure of attractiveness of place i
- \( A_j \) = measure of attractiveness of place j
- \( d_{ij} \) = distance between places i and j
- \( G \) = a constant of proportionality
Scoring Function

\[ S_{ij} = \frac{T_{ij}}{G} = \frac{A_i \cdot A_j}{d_{ij}^2} \]

S_{ij} is the interactivity potential between place i and place j

Used to estimate demand for transportation between two places
Interactivity Between Businesses in Cluster

\[ S_{ij} = \frac{B_i \cdot B_j \cdot c_{ij}}{d_{ij}^2} \]

\( B_i \) and \( B_j \) are the (total) sales or employment of the two businesses \( i \) and \( j \), respectively.

\( d_{ij} \) is the distance between the two businesses,

\( c_{ij} \) is the input-output coefficient between businesses \( i \) and \( j \) and

\( S_{ij} \) is the interactivity potential between business \( i \) and business \( j \).

\( n \) is the number of businesses in the cluster.
Economies and Network Effects for All Businesses in Cluster

\[ \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{B_i \cdot B_j \cdot c_{ij}}{d_{ij}^2} \]

- Takes Distance Into Account in Estimation
- Much of Logistics – Movement of Goods
- Cluster Participants in Close Proximity – Higher Score
Economies and Network Effects for All Businesses in Cluster

- More Businesses Added to Cluster – Scoring Function Increases
- Network Effects – Incorporated through I-O Coefficients
- Larger Coefficients – Greater Network Effects – Interaction Between Businesses Greater
- Can Implement Using Secondary Data Sources – Economic Census, Map Distances, I-O Tables
A Production Function Formulation

- Focuses on Agglomeration Economies
- Estimates Impacts of Number of Firms on Productivity

Let:

\[ Q_i = \text{GDP or production (in physical units) in sector } i \]
\[ E(.) = \text{efficiency function} \]
\[ L_i = \text{labor in sector } i \]
\[ K_i = \text{capital in sector } i \]
A Production Function Formulation

Production Function:

\[ Q_i = E(.) \ F (L_i, K_i) \]

Production Per Unit of Capital in Sector i:

\[ q_i = E(.) \ F (L_i / K_i) \]

Since E(.) represents the efficiency of the production function, it can be used to portray Economies of Agglomeration
A Production Function Formulation

- Let \( E() \) be a function of the number of firms in sector \( i \) and a vector of other relevant variables \((x)\)
- Then:

\[
q_i = E(n_i, X_i) \frac{F(L_i/K_i)}{n_i}
\]

\[
q_i = f(n_i, L_i/K_i, X_i)
\]
A Production Function Formulation

Estimation Equation:

\[ \ln q_i = \beta_0 + \beta_1 \ln n_i + \beta_2 \ln L_i / K_i + \beta_3 \ln X_i \]

Agglomeration Effects reflected in the impact of number of firms on productivity of sector i
# Application to the Panama Logistic Services Cluster

## Cluster Components

<table>
<thead>
<tr>
<th>Direct</th>
<th>Indirect</th>
<th>Induced</th>
<th>Parallel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canal Operation</td>
<td>Shipping Lines</td>
<td>Ports</td>
<td>Air Hub</td>
</tr>
<tr>
<td></td>
<td>Shipping Agencies</td>
<td>Colon Free Zone</td>
<td>Colon Free Zone</td>
</tr>
<tr>
<td></td>
<td>Ship Chandlers</td>
<td>Canal Tourism</td>
<td>Merchant Marine</td>
</tr>
<tr>
<td></td>
<td>Ship Repair and Maintenance</td>
<td>Logistics Management</td>
<td>Telecommunications</td>
</tr>
<tr>
<td></td>
<td>Launch and Pilot Services</td>
<td>Railway</td>
<td>City of Knowledge</td>
</tr>
<tr>
<td></td>
<td>Services</td>
<td>Export Processing</td>
<td>Legal Services</td>
</tr>
<tr>
<td></td>
<td>Dredging</td>
<td>Zones</td>
<td>Ship Grading and Classification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intermodal Services</td>
<td>Maritime Court</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cruiseship Tourism</td>
<td>Public Services</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Container Repair</td>
<td>Financial Intermediation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land Transportation</td>
<td>Education and Training</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Insurance</td>
</tr>
</tbody>
</table>
Cluster Components

- Direct
  - Foreign exchange contributions of the Canal

- Indirect
  - Derived from the provision of additional services to transiting vessels

- Induced
  - Those activities located in Panama as a result of the existence of the Canal, but depending on international and regional markets for their growth

- Parallel
  - Other related economic activities, which do not depend or were induced by the Canal
Data Analysis - Gravity Model Formulation

- ACP Economic Impact Study Report - Estimates of total production for sectors of the Panamanian economy in 2001

- Seven sectors were chosen for detailed analysis. These are the Canal, the Colon Free Trade Zone, Tourism, Bunkering & Shipping Agencies, Shipping Companies, Ship Chandlers and Ports.
## Sector Production (2001)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canal</td>
<td>$868,504</td>
</tr>
<tr>
<td>Colon Free Trade Zone</td>
<td>$5,606,172</td>
</tr>
<tr>
<td>Tourism</td>
<td>$48,000</td>
</tr>
<tr>
<td>Bunkering &amp; Shipping Agencies</td>
<td>$175,014</td>
</tr>
<tr>
<td>Shipping companies</td>
<td>$3,838</td>
</tr>
<tr>
<td>Ship Chandlers</td>
<td>$15,782</td>
</tr>
<tr>
<td>Ports</td>
<td>$172,300</td>
</tr>
</tbody>
</table>
Input-Output Coefficients

- ACP Economic Study
  - First built map of intersectorial relations based on questionnaire
  - Detailed interviews conducted with representative businesses
  - Qualitative classification of degree of linkage among cluster activities developed
  - I-O coefficients developed – both direct and indirect effects
Matrix of Coefficients

- I-O Coefficients Slightly Modified
  - Report divides tourism was divided into cruise ship tourism and canal tourism
  - Combined into one sector called tourism
  - I-O Coefficients show one cluster component as a dependent variable, the other as explanatory
  - This study - Interested in total level of interconnectedness between two cluster components
  - Components of two cluster activities added - One measure of connectivity between two cluster activities
## Matrix of Combined I-O Coefficients

<table>
<thead>
<tr>
<th></th>
<th>Canal</th>
<th>Colon FTZ</th>
<th>Tourism</th>
<th>Burkering &amp; Shipping Agenc.</th>
<th>Shipping companies</th>
<th>Ship Chandlers</th>
<th>Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canal</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colon FTZ</td>
<td>0.02</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tourism</td>
<td>0.03</td>
<td>0.03</td>
<td>0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burkering &amp; Shipping Agencies</td>
<td>1.09</td>
<td>0.05</td>
<td>0.01</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shipping companies</td>
<td>0.4</td>
<td>0.2</td>
<td>0</td>
<td>0.02</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ship Chandlers</td>
<td>0.4</td>
<td>0.01</td>
<td>0</td>
<td>0.05</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Ports</td>
<td>0.18</td>
<td>0.25</td>
<td>0.03</td>
<td>0.5</td>
<td>0.21</td>
<td>0.5</td>
<td>0</td>
</tr>
</tbody>
</table>
Gravity Model Results
(Hundreds of Millions of Dollars)

<table>
<thead>
<tr>
<th></th>
<th>Canal</th>
<th>Colon FTZ</th>
<th>Tourism</th>
<th>Bunkering &amp; Shipping Agencies</th>
<th>Shipping Companies</th>
<th>Ship Chandlers</th>
<th>Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canal</td>
<td>-</td>
<td>15,581</td>
<td>200</td>
<td>26,509</td>
<td>9,728</td>
<td>877</td>
<td>2,693,578</td>
</tr>
<tr>
<td>Colon Free Trade Zone</td>
<td>15,581</td>
<td>-</td>
<td>861</td>
<td>196,232</td>
<td>17,213</td>
<td>3,539</td>
<td>965,943</td>
</tr>
<tr>
<td>Tourism</td>
<td>200</td>
<td>861</td>
<td>6,451</td>
<td>13</td>
<td>-</td>
<td>-</td>
<td>992</td>
</tr>
<tr>
<td>Bunkering &amp; Shipping Agencies</td>
<td>26,509</td>
<td>196,232</td>
<td>13</td>
<td>4,901</td>
<td>54</td>
<td>552</td>
<td>60,310</td>
</tr>
<tr>
<td>Shipping companies</td>
<td>9,728</td>
<td>17,213</td>
<td>-</td>
<td>54</td>
<td>-</td>
<td>-</td>
<td>555</td>
</tr>
<tr>
<td>Ship Chandlers</td>
<td>877</td>
<td>3,539</td>
<td>-</td>
<td>552</td>
<td>-</td>
<td>-</td>
<td>5,438</td>
</tr>
<tr>
<td>Ports</td>
<td>2,693,578</td>
<td>965,943</td>
<td>992</td>
<td>60,310</td>
<td>555</td>
<td>5,438</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>2,746,473</td>
<td>1,199,369</td>
<td>8,518</td>
<td>288,571</td>
<td>27,550</td>
<td>10,407</td>
<td>3,726,818</td>
</tr>
<tr>
<td>% of Total</td>
<td>34.30%</td>
<td>14.98%</td>
<td>0.11%</td>
<td>3.60%</td>
<td>0.34%</td>
<td>0.13%</td>
<td>46.54%</td>
</tr>
</tbody>
</table>
Gravity Model Results

- Ports are the most important component
  - Account for over 46% of the total estimate of cluster economies and network effects
- The second most important component is the Canal itself
  - Ports have many inter-relationships with other cluster activities that the Canal may not have
- Third most important element is the Colon Free Trade Zone
  - Linkages with other cluster activities need to be strengthened
Activities Within an Individual Cluster Component

- Canal - most important linkage with ports
  - Interaction with the ports accounting for 98% of the total estimate of Canal contribution to cluster economies and network effects
- FTZ - most important linkage with ports
  - Accounts for 80% of variation
- Tourism - most important element is itself since combination of cruise ship and canal tourism
Activities Within an Individual Cluster Component

- Colon Free Trade Zone accounts for 68% of the Bunkering & Shipping Agencies component
  - Ports also provide an important linkage
- Chandlers are most closely linked to the ports and the FTZ
  - Each accounting for 52% and 34% of contribution of that component
Conclusions

- The gravity model provides an estimate of maritime cluster economies and supply chain network effects
- Estimates over time will help to understand the growth of these effects
- Model helps to provide an understanding of which components are most important to the cluster and which activities are most closely linked
Conclusions

- The model allows us to peer inside the cluster to understand the inner workings of linkages among the cluster elements.
- This information can play an important role in shaping public policy regarding cluster development and enhancement.
Future Work

- Gravity Model – Expand the number of cluster components included in the analysis
- Production Function Formulation – Perform econometric estimation of the function
- Cluster Development Over Time – ACP currently developing economic model of Panama economy. Can be used to understand how cluster has changed over time
- Public Policy – Investigation of how public policy tools can best be focused to enhance cluster development