Impact of scale increase of container ships on the generalised chain cost

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Contents

1. Rationale and setting
2. Research questions
3. Literature review
4. Model structure: maritime, port and hinterland
5. Application and testing:
   - Asia – Europe
   - US - Europe
6. Conclusions
Rationale and setting: ship size

Evolution container ship size

- Average ship size deployed fleet
- 8K+ TEU Containership Fleet Development
Rationale and setting: the chain
Research questions:

1. Does vessel scale increase lead to chain economies of scale? And in what section of the chain does it do so?
2. Is the effect route-specific, or generalizable?
Literature: general

- Three building blocks
- Before 1973:
  - Svendsen (1958): descriptive
  - Thorburn (1960): maritime and port pricing
  - Heaver and Studer (1972): ship → port
- After 1973:
  - Jansson and Shneerson (1982): pricing and queuing

Source: EC
Literature: the ship

• Technical:
  • Napier (1865): analytical
  • Bendfold (1966): iterative
  • Watson (1998): parametric

• Economic:
  • Cullinane and Khanna (1999): 8,000 TEU
  • Wijnolst et al. (1999): 18,000 TEU
  • Sys et al. (2008): 12,500 TEU
  • Ronen (2010), Khor et al. (2012): speed

Source: EC
Literature: ports and hinterland

- Roso et al. (2009), Rodrigue et al. (2010): role of inland terminals
- Blauwens et al. (2012): time and distance costs
- Grosso (2011): intermodal comparison
  - Transportation
  - Handling
  - Time consumption
  - (External costs)
The model: structure

Port choice in Hamburg-Le Havre range

Selection of a container loop and a ship in that loop (4.3)

Ship model

Port model 1
Port model 2
Port model 3
Port model 4
Port model 5
Port model 6

Hinterland model

Output as total GC per hinterland region (4.5)

Origin/Destination (Port in a loop)

Total chain

Destination/Origin (NUTS-2 regions)
The model: input

- Container loop
- Container ship
- Port + terminal
- Hinterland
- Cargo properties (VoT)
The model: the chain

In total 216 hinterland regions in the model.
The model: the ship

- Route model: distances
- Design model: size and propulsion (parametric)
- Cost model:
  - Operational (crew, insurance, consumables, repair/maintenance, management)
  - Voyage (fuel, lubricants, canal dues, port cost)
  - Capital (interest + depreciation)
### SHIP MAIN INPUT DATA

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select ship size</td>
<td>13,118</td>
<td>[TEU]</td>
</tr>
<tr>
<td>Ship size Nom cap (14 ton/TEU)</td>
<td>8,841</td>
<td>[TEU]</td>
</tr>
<tr>
<td>Actual average ship size in loop (slot capacity)</td>
<td>13,459</td>
<td>[TEU]</td>
</tr>
<tr>
<td>Analysis on nom. Cap or slot capacity</td>
<td>slot</td>
<td>[-]</td>
</tr>
<tr>
<td>Selected number of ships in the loop</td>
<td>11</td>
<td>[-]</td>
</tr>
<tr>
<td>Actual number of ships in the loop</td>
<td>11</td>
<td>[-]</td>
</tr>
<tr>
<td>PAYLOAD</td>
<td>80%</td>
<td>[-]</td>
</tr>
<tr>
<td>% of design SPEED</td>
<td>90%</td>
<td>[%]</td>
</tr>
<tr>
<td>Sailing speed</td>
<td>22.50</td>
<td>[knots]</td>
</tr>
<tr>
<td>HFO</td>
<td>508</td>
<td>[EUR/tonne]</td>
</tr>
<tr>
<td>MDO</td>
<td>750</td>
<td>[EUR/tonne]</td>
</tr>
<tr>
<td>Ext_cost sea transport</td>
<td>No</td>
<td>[-]</td>
</tr>
</tbody>
</table>
The model: the port

- Shipping company
  - Port Authority
  - Pilotage
  - Towing
  - Terminal 1
  - Terminal 2
  - Terminal 3
  - Terminal 4

Competition between ports

Competition in the port

Hinterland transport
The model: the port (2)

- **Port shipping:**
  - Crew
  - Operational
  - Function of size and type of ship
  - Sailing and waiting times (buoy, lock, berth, (un-)loading)
  - External congestion cost

- **Port authority:**
  - Vessel size
  - Cargo (un-)loaded
The model: the port (3)

- Third parties:
  - Towage
  - Pilotage
  - Cargo handling
The model: the port (4)

1) Intra port Shipping cost
2) Port dues
3a) Tug(s) and Pilotage
3b) Cargo handling cost
The model: the port (5)

\[ P(i) = \frac{e^{-\lambda} \lambda^i}{i!} \]

\[ P(t) = \mu e^{-t\mu} \]
### PORT MAIN INPUT DATA

<table>
<thead>
<tr>
<th></th>
<th>Port_1</th>
<th>Port_2</th>
<th>Port_3</th>
<th>Port_4</th>
<th>Port_5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original ports in North West EU</td>
<td>Hamburg</td>
<td>Bremen</td>
<td>Zeebrugge</td>
<td>Rotterdam</td>
<td>LE HAVRE</td>
</tr>
<tr>
<td>Select ports</td>
<td>Hamburg</td>
<td>BREMEN</td>
<td>ZEEBRUGGE</td>
<td>ROTTERDAM</td>
<td>LE HAVRE</td>
</tr>
<tr>
<td>Select terminals</td>
<td>Terminal 3</td>
<td>Terminal 3</td>
<td>Terminal 3</td>
<td>terminal 3</td>
<td>terminal 1</td>
</tr>
<tr>
<td>% of cargo onboard unloaded at selected terminal</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>% of cargo onboard loaded at selected terminal</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>EXT_cost in the port region</td>
<td>No</td>
<td>[-]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congestion cost in the port region</td>
<td>No</td>
<td>[-]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The model: the hinterland
The model: the hinterland (2)

- Network model: distances
- Generalized cost model

\[ GC_i = OPC_i + C_{\text{handling}} + U_i \cdot VoT \]

\[ OPC_i = u_i \cdot U_i + d_i \cdot D_i \]
## The model: the hinterland (3)

### HINTERLAND MAIN INPUT DATA

<table>
<thead>
<tr>
<th></th>
<th>Selection</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select core hinterland</td>
<td>Yes</td>
<td>[-]</td>
</tr>
<tr>
<td>Select GDP criteria</td>
<td>All</td>
<td>[-]</td>
</tr>
<tr>
<td>Select GDP data (on GDP/cap. or GDP per Region)</td>
<td>[EUR/cap.]</td>
<td>[-]</td>
</tr>
<tr>
<td>Select GDP data YEAR</td>
<td>2010</td>
<td>[-]</td>
</tr>
<tr>
<td>% afwijing hinterland fuel cost</td>
<td>0%</td>
<td>[-]</td>
</tr>
<tr>
<td>Ext_cost Hinterland</td>
<td>No</td>
<td>[-]</td>
</tr>
</tbody>
</table>
The model: the chain

In total 216 hinterland regions in the model
The model: the cargo

<table>
<thead>
<tr>
<th>Cargo properties</th>
<th>Collected data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value Container import (average)</td>
<td>€ 40,804</td>
</tr>
<tr>
<td>Value Container export (average)</td>
<td>€ 65,286</td>
</tr>
<tr>
<td>Deprecation per year</td>
<td>3%</td>
</tr>
<tr>
<td>VoT (import)</td>
<td>€ 0.14</td>
</tr>
<tr>
<td>VoT (export)</td>
<td>€ 0.22</td>
</tr>
</tbody>
</table>

[EUR/cont]

[EUR/TEU.h]
The model: the chain loops

13,200 TEU vessel
22.5 knots
80% occupation
The model: the chain loops
The model: the chain loops
The model: the chain loops
Application and testing: RQ1

- Average cost per hinterland region, with factor related to GDP

\[ AGC_i = \sum_{j=1}^{n} f_j GC_{i,j} \]

\[ f_j = \frac{\left( \frac{GDP}{Capita} \right)_j . Capita_j}{\sum_{j=1}^{n} \left( \frac{GDP}{Capita} \right)_j . Capita_j} \]
Application and testing: RQ1

- Average share of chain element costs per hinterland region, with factor related to GDP

\[
ACC_i = \sum_{j=1}^{n} f_j CC_{i,j}
\]
Application and testing: RQ2
Application and testing: RQ2

- Average cost per hinterland region, with factor related to GDP
Application and testing: RQ2

- Average share of chain element costs per hinterland region, with factor related to GDP
Conclusion

• RQ1: Generalized cost decreases with growing ship size, and share of maritime section decreases, while share of hinterland section increases.

• RQ2: The observations do depend on the considered route somehow: distance sailed and port capacity do have a clear impact.
Thank you!

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