Vertical Integration and its Implications to Port Expansion

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- Introduction
- Literature
- Model
  - Basic model
  - Vertical integration
  - Analysis
- Conclusions

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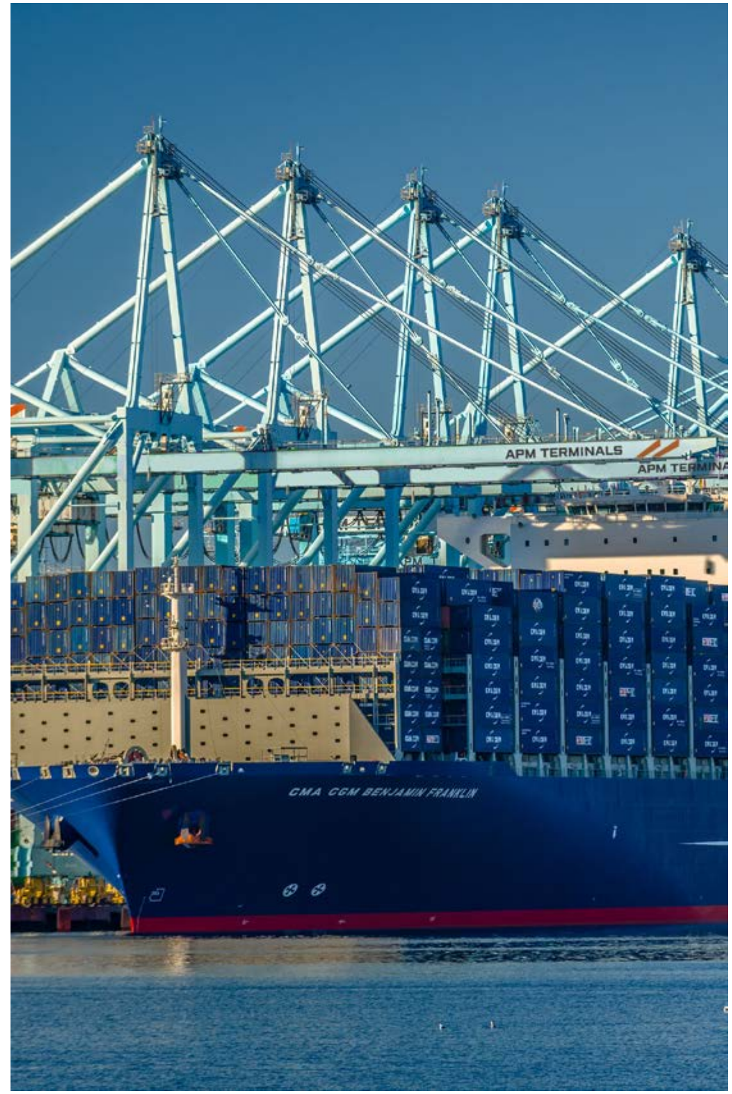
Introduction

- Vertical integration
  - Any type of cooperation deeper than arm’s length cooperation
- Shipping lines
  - Companies/groups providing container liner shipping service as main business
- This study develops an analytical model in order to study **the effects of vertical integration, with a focus on shipping lines’ investment in ports’ capacity.**

Introduction – Background

- Significant changes in shipping industry
  - Shipping lines' involvement in port management/terminal operation (Drewry, 2017)
  - Increasing requirement on terminal facilities (Drewry, 2016)
- Terminal operation as a mature market
  - Low market growth vs. requirements on port upgrade
  - Investment from shipping companies
- Shipping lines' involvement in terminal operation
  - Involvement methods: Direct control vs. Through sister companies; Concession agreement model, joint venture with other investors (Botham, 2014; Yip et al., 2014)
  - Dedicated usage vs. open to other carriers
- Reluctance from the local interests and policymakers

Contents



Literature

- Vertical integration as a well-studied topic in economics
  - Complex and dependent on market structure
  - For the integrated company: extract more monopoly profit and bargaining power (Riordan 2008), restore market power (Rey & Tirole 2007)
  - For unintegrated companies: increased cost (Chen 2001)
  - For consumers and social welfare: eliminate double-marginalisation (Spengler 1950), more monopoly power of the integrated company
- Vertical integration in the maritime industry
  - For shipping lines: dockside equipment and well-trained labour force (Casson 1986), efficiency and reliability (Midoro, Musso, & Parola 2005), lower risks (Notteboom & Rodrigue 2012), infrastructural requirements (van de Voorde & Vanelslander 2009), etc.
  - For port authorities: obtain more investment (Lun, Lai & Cheng 2010; Notteboom & Rodrigue 2009; Psaraftis & Pallis 2012)
  - For terminal operators: global competitiveness (Lee & Meng 2014), negotiation power (Lee & Song 2014)

Literature

- Vertical integration in other transport sectors
  - Airline-airport: strengthen participating firms' profits; mixed effects on competition and welfare (Barbot 2009; Barbot, D'Alfonso, Malighetti & Redondi 2013; D'Alfonso & Nastasi 2012, 2014; Fu, Homsombat & Oum 2011)
  - Rail infrastructure operator-rail service provider: vertical integration can be helpful (Preston 1996; Ferreira 1997; Growitsch & Wetzel 2009)

- Summary of literature and current research gaps
  - Vertical integration has both positive and negative effects
  - Integrated company can normally be better off; Non-integrated companies are harmed; Implications to market and customers are mixed
  - Few studies have investigated transport infrastructure investment

Contents

Model

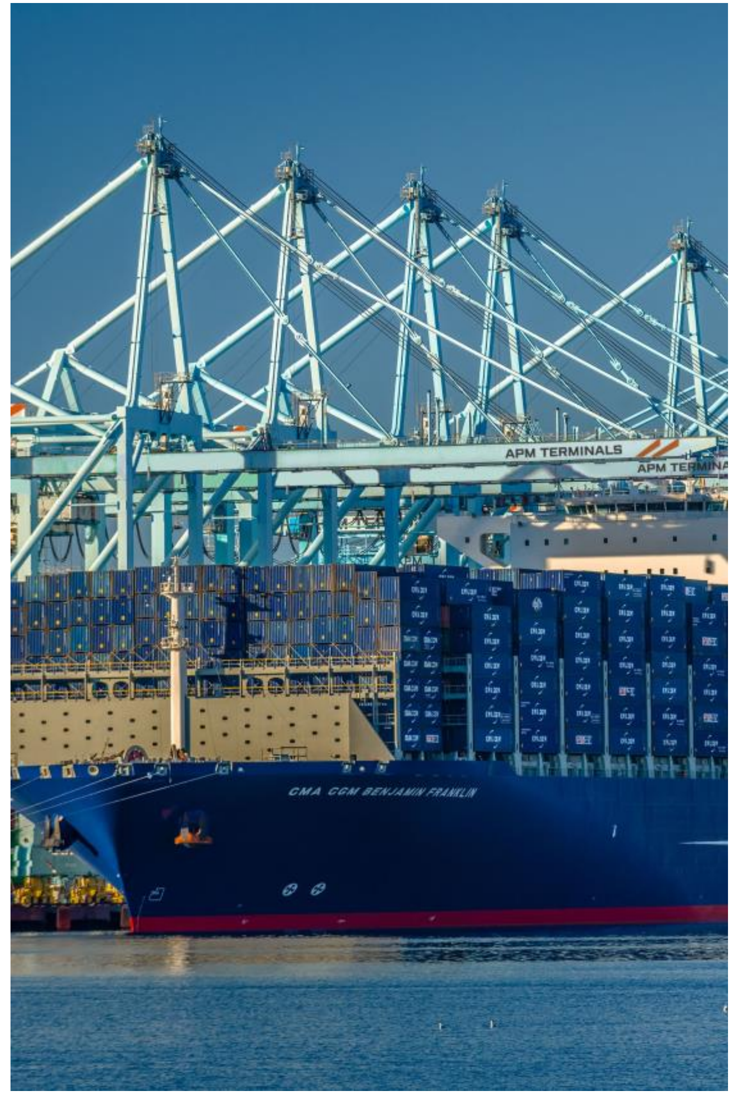
Overview

- One port authority
- One terminal
- N competing carriers

Two scenarios

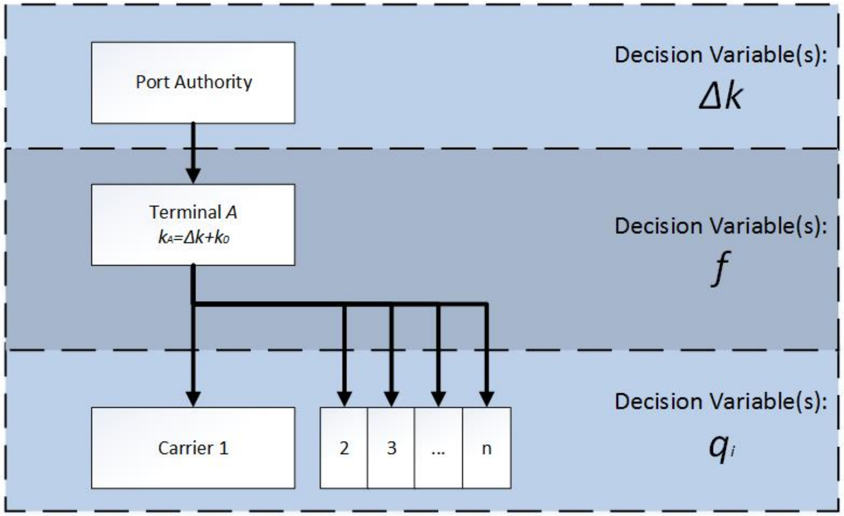
- Basic model
  - No carrier is involved in terminal operation
- Vertical integration
  - One of the N carriers is involved in terminal operation, by investing in capacity expansion and share revenue in return (no service quality priority is considered)

Contents



Model formulation – basic model

- One port authority
  Stage one: mandates extra capacity to be invested by the terminal operator, denoted as Δk. The capital cost is therefore $r\Delta k$.
- One terminal operator
  Stage two: sets a port charge f per container with capacity $k = \Delta k + k_0$ and constant marginal cost c.
- N shipping companies
  Stage three: carriers compete in quantity q_i to maximise their individual profits. The port throughput is $Q \equiv \sum_{i=1}^{N} q_i$ and the cost of delay per container is $\gamma \frac{Q}{k}$.

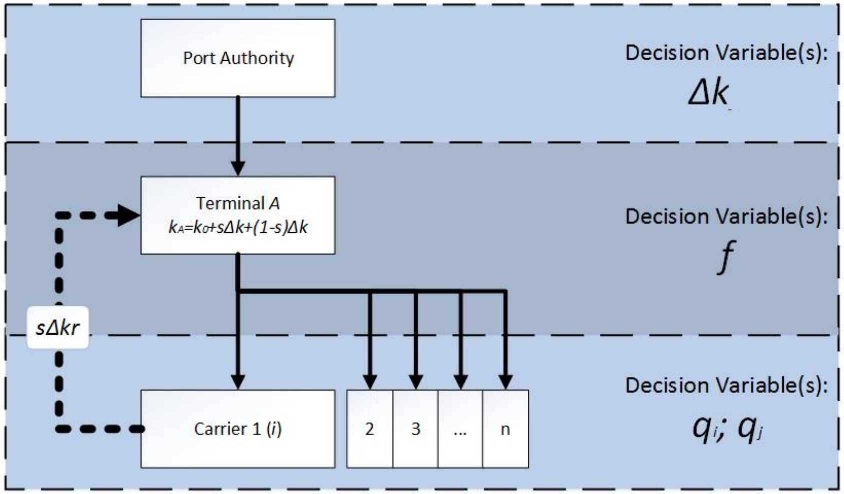


Base scenario of the model

Contents

Model formulation – vertical integration

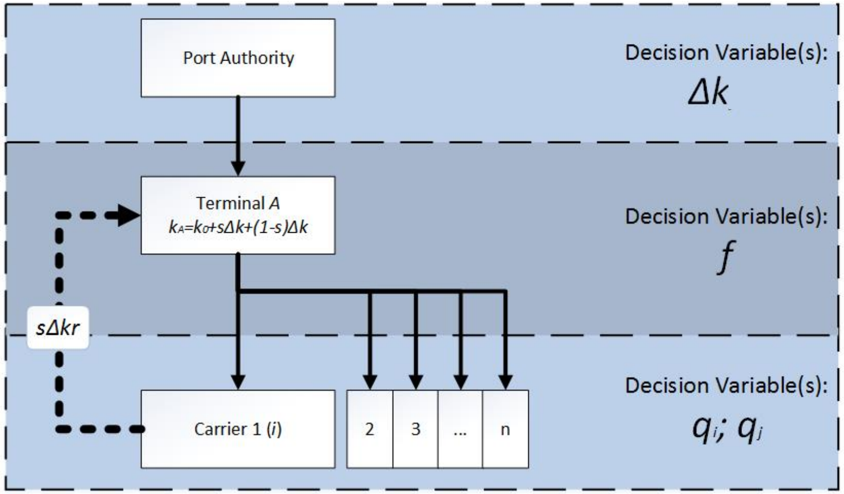
- Through joint venture
- Carrier i invests in the terminal expansion, and shares terminal revenue proportionally
- Examples:
  - Waigaoqiao Phase-4
    - Shanghai International Port Group
    - APM Terminals



Vertical integration through joint venture

Model formulation – vertical integration

- One port authority
  Stage one: decides capacity expansion Δk, given the share that the carrier i can invest in the capacity expansion s.
- One terminal operator
  Stage two: sets a port charge f
- N shipping companies
  Stage three: carriers compete in quantity q_i, q_j to maximise their individual profits.



Vertical integration through joint venture

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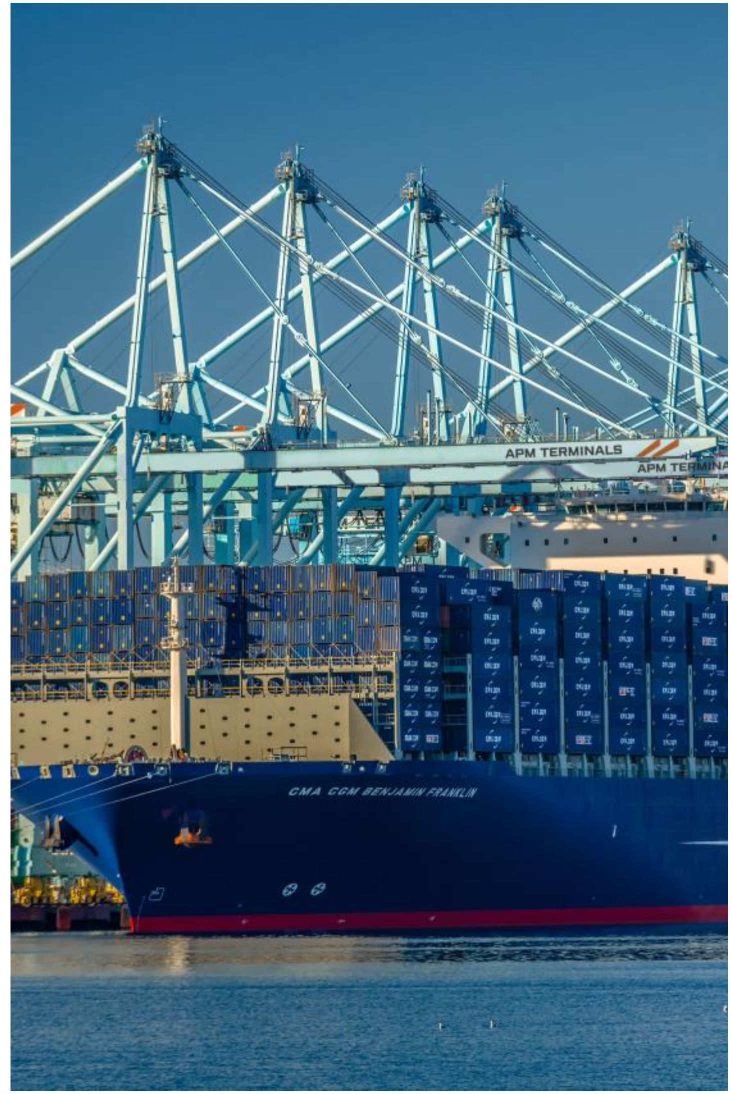

Model analysis

- Proposition 1: *The vertical integration strategy leads to higher port charge so that* $f_V > f_B$.
  - Corollary 1: *As carrier* i *invests in a higher proportion of the terminal's capacity, the port charge will be higher.*
  - Corollary 2: *The integrated carrier has a higher output level than that of the non-integrated carriers.*
- Proposition 2: *The vertical integration strategy leads to larger port capacity thus that* $\Delta k_V \geq \Delta k_B$. *Moreover, more capacity is added as carrier* i *investments a larger share in the expansion project, i.e.,* $\partial \Delta k_V / \partial s > 0$.
  - Corollary 3: *Vertical integration leads to larger market outputs*, i.e., $Q_V \geq Q_B$.
  - Corollary 4: *The vertical integration reduces delay costs*, i.e., $d_V \leq d_B$.

Empirical analysis

- Based on Lloyd's List World Top 100 Container Ports (2018)
- 63 VI ports vs. 37 non-VI ports, VI ports tend to have
  - Higher throughput in 2017: 722.75 thousand TEU vs. 358.48 thousand TEU
  - Longer berth: 5319.70 m vs. 2776.43 m
  - Larger terminal yard area: 266.70 ha vs. 126.16 ha
  - More ship to shore cranes: 48.16 vs. 25.95
  - More automated stacking cranes: 117.65 vs. 56.00
  - Lower per STS crane throughput per year: 143.65 kTEU/crane vs. 171.54 kTEU/crane

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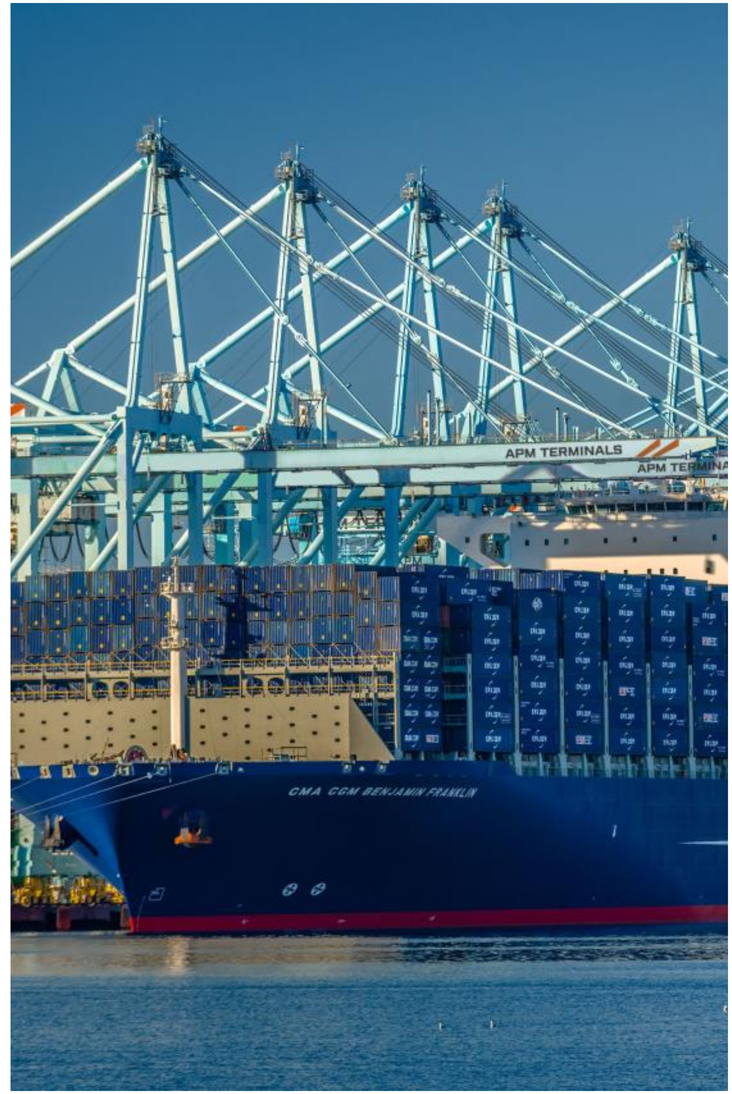

Conclusions

- This paper develops an economic model in which the decisions of port authority, terminal operator and shipping lines are considered in a multi-stage game.
- Objective function of the port authority is specified so that a range of possible scenarios can be studied within one framework.
- Vertical integration between terminal operator and a shipping line leads to :
  - Higher port capacity
  - Higher port charge
  - Higher market output
  - Higher consumer surplus
  - Lower delay costs

  - At the expenses of the non-integrated shipping lines
  - Uncertain overall social welfare change

Conclusions

- Future research
  - Other specifications on demand and delay costs
  - Consider inter-terminal competition and inter port competition

Vertical integration and shipping lines' route design

Are shipping lines more likely to choose ports they are involved in?

Data collection – port information

- 282 ports' information, 166 are covered in collected shipping routes
- Categorised into 14 regions
- Hinterland GDP
- Transport volume in 2016
- Whether the port is involved by shipping lines

Data collection – route information

- 9 carriers from 3 alliances (75%)
- Shared routes are treated as distinct services
- 65 from 2M; 237 from OCEAN; 119 from THE
- One-way PoCs
- One-way days
- One-way distance

	Number of routes	Average One-way PoCs	Average One-way days	Average One-way distance(km)	Average distance between PoCs(km)	Average Speed (km/d)
2M	65	7	33	15733	2601	485.72
Maersk	37	7	33	15573	2667	490.86
MSC	28	7	34	15944	2514	478.94
OCEAN	237	6	29	13402	2644	478.53
CMACGM	65	6	30	13732	2713	465.87
COSCO	72	6	29	13507	2655	480.08
EG	53	6	28	13756	2722	495.82
OOCL	47	6	27	12385	2443	474.15
THE	119	6	28	13764	2621	499.46
HL	39	6	29	14507	2659	514.84
ONE	46	6	29	13870	2566	487.88
YM	34	6	26	12769	2650	497.48
Total	421	6	29	13864	2631	485.55

Choice of Asia PoCs

- Yangtze River Delta (YRD)
  - Ningbo, Shanghai, Lianyungang
- Pearl River Delta (PRD)
  - Hong Kong, Shekou, Nansha, Yantian
- North China (NC)
  - Qingdao, Dalian, Xingang
- Fujian (FJ)
  - Xiamen, Fuzhou
- Korea (KOR)
  - Busan, Incheon, Kwangyang, Ulsan
- Japan (JAP)
  - Tokyo, Kobe, Yokohama, Nagoya, Osaka, Hakata, Shimizu, Sendai
- Taiwan (TW)
  - Kaohsiung, Taipei, Keelung

Example of one data entry

Carrier	Alliance	Route	Port	Poc	Own involvement	Alliance involvement	Volume in 2016	Hinterland GDP
CMACGM	OCEAN	China India Middle East Express 2N	Yantian	0	0	1	11696	
CMACGM	OCEAN	China India Middle East Express 2N	Shekou	0	0	0	5931	
CMACGM	OCEAN	China India Middle East Express 2N	Nansha	0	0	1	15953	
CMACGM	OCEAN	China India Middle East Express 2N	Hong Kong	0	0	1	19813	
CMACGM	OCEAN	China India Middle East Express 2N	Qingdao	1	0	1	18010	
CMACGM	OCEAN	China India Middle East Express 2N	Dalian	1	0	1	9614	
CMACGM	OCEAN	China India Middle East Express 2N	Xingang	1	0	1	14490	
CMACGM	OCEAN	China India Middle East Express 2N	Shanghai	0	0	1	36537	
CMACGM	OCEAN	China India Middle East Express 2N	Ningbo	1	0	1	21560	
CMACGM	OCEAN	China India Middle East Express 2N	Lianyungang	0	0	1	4703	
CMACGM	OCEAN	China India Middle East Express 2N	Xiamen	0	1	0	9614	
CMACGM	OCEAN	China India Middle East Express 2N	Fuzhou	0	0	0	2650	
CMACGM	OCEAN	China India Middle East Express 2N	Tokyo	0	0	0	4700	
CMACGM	OCEAN	China India Middle East Express 2N	Kobe	0	0	0	2801	
CMACGM	OCEAN	China India Middle East Express 2N	Yokohama	0	0	0	2787	
CMACGM	OCEAN	China India Middle East Express 2N	Nagoya	0	0	0	2658	
CMACGM	OCEAN	China India Middle East Express 2N	Osaka	0	0	0	1952	
CMACGM	OCEAN	China India Middle East Express 2N	Hakata	0	0	0	897	
CMACGM	OCEAN	China India Middle East Express 2N	Shimizu	0	0	0	428	
CMACGM	OCEAN	China India Middle East Express 2N	Sendai	0	0	0	246	
CMACGM	OCEAN	China India Middle East Express 2N	Busan	1	1	0	19850	
CMACGM	OCEAN	China India Middle East Express 2N	Incheon	0	0	0	2680	
CMACGM	OCEAN	China India Middle East Express 2N	Kwangyang	1	0	0	2250	
CMACGM	OCEAN	China India Middle East Express 2N	Ulsan	0	0	0	423	
CMACGM	OCEAN	China India Middle East Express 2N	Kaohsiung	0	0	1	10645	
CMACGM	OCEAN	China India Middle East Express 2N	Taipei	0	0	1	1477	
CMACGM	OCEAN	China India Middle East Express 2N	Keelung	0	0	0	1388	

Current problem

- Pick any/j data modelling
- Correlation between selections
- Only cross sectional data available

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Appendix 1

For base scenario

- FOC of carrier *i*'s profit maximization is

$$p(Q) - f - \gamma \frac{Q}{k} + q_i \left(\frac{\partial p}{\partial Q} - \frac{\gamma}{k} \right) = 0$$

- Apply symmetry

$$q_{i,B} = \frac{(a - f)}{(N + 1)(b + \gamma/k)}$$

$$Q_B = \frac{N(a - f)}{(N + 1)(b + \gamma/k)}$$

- FOC of terminal's profit maximization is

$$\frac{\partial Q}{\partial f}(f - c) + Q = 0$$

- We have

$$f_B = (a + c)/2$$

- Therefore

$$q_{i,B} = \frac{a - c}{2(N + 1)(b + \gamma/k_B)}$$

$$Q_B = \frac{N(a - c)}{2(N + 1)(b + \gamma/k_B)}$$

Appendix 1

For vertical integration scenario

– FOC of carriers' profit maximization is

$$\text{For i: } p(Q) - f - \gamma\frac{Q}{k} + q_i\left(\frac{\partial p}{\partial Q} - \frac{\gamma}{k}\right) + \frac{s\Delta k}{k}\cdot(f - c) = 0$$

$$\text{For j: } p(Q) - f - \gamma\frac{Q}{k} + q_j\left(\frac{\partial p}{\partial Q} - \frac{\gamma}{k}\right) = 0$$

– Apply symmetry for other carriers

$$q_{i,V} = \frac{(a - f) + (f - c)Ns\Delta k/k}{(N + 1)(b + \gamma/k)}$$

$$q_{j,V} = \frac{a - f - (f - c)s\Delta k/k}{(N + 1)(b + \gamma/k)}$$

$$Q_V = \frac{N(a - f) + s\Delta k(f - c)/k}{(N + 1)(b + \gamma/k)}$$

– From FOC of terminal's profit maximization, we have

$$\frac{\partial Q}{\partial f}(f - c) + Q = 0$$

– Therefore

$$f_V = \frac{N(a + c) - 2cs\Delta k_V/k_V}{2(N - s\Delta k_V/k_V)}$$

$$Q_V = \frac{N(a - c)}{2(N + 1)(b + \gamma/k_V)}$$

Appendix 1

Proof of ***Proposition 1***: It is easy to know that $\partial f_V / \partial N < 0$ and $\lim_{N \to \infty} f_V = (a + c)/2 = f_B$. Therefore, we have $f_V > f_B$.

Moreover, examining the effect of carrier *i*'s investment share on port charge, we find $\frac{\partial f_V}{\partial s} = \frac{N(a-c)\Delta k/k}{2(N-s\Delta k/k)^2} > 0$, which leads to the following corollary.

Appendix 2

For Base scenario

– FOC of port authority's objective is

$$\theta\left(-\frac{\partial \mathrm{p}}{\partial Q}\cdot\frac{\partial \mathrm{Q}}{\partial k}\cdot \mathrm{Q}\right)+\frac{\partial \mathrm{Q}}{\partial k}(\mathrm{f}-\mathrm{c})+\mathrm{Q}\frac{\partial \mathrm{f}}{\partial k}=\mathrm{r}$$

– Substitute p and f, we have

$$\theta\left(\frac{\partial \mathrm{Q}}{\partial k}\cdot \mathrm{bQ}\right)+\frac{\partial \mathrm{Q}}{\partial k}(\mathrm{f}-\mathrm{c})=\mathrm{r}$$

For vertical integration scenario

– FOC of port authority's objective is

$$\theta\left(\frac{\partial \mathrm{Q}_V}{\partial k_V}\cdot \mathrm{bQ}_V\right)+\frac{\partial \mathrm{Q}_V}{\partial k_V}(\mathrm{f}_V-\mathrm{c})+\mathrm{Q}_V\frac{\partial \mathrm{f}_V}{\partial \Delta k_V}=r$$

Appendix 2

Proof of ***Proposition 2***: we need to compare $\Delta \mathrm{k_B}$ determined by (14) and $\Delta \mathrm{k_V}$ determined by (27). Note that the LHS of (14) has no relationship with the parameter s. The LHS of (27) has a positive relationship with s, because $\partial \mathrm{Q}_V/\partial s = 0$, $\partial^2 \mathrm{Q}_V/\partial k_V \partial s = 0$, $\partial \mathrm{f}_V/\partial s > 0$and $\partial^2 \mathrm{f}_V/\partial \Delta k_V \partial s > 0$. When $s = 0$, the LHS of (14) equals to the LHS of (27), which leads to $\Delta k_V = \Delta k_B$. When $0 < s \leq 1$, the LHS of (14) is constant, whereas the LHS of (27) increases, if $\Delta k_V = \Delta k_B$. Thus, in order to keep both (14) and (27) hold simultaneously, $\Delta k_V \geq \Delta k_B$ must hold because $\partial^2 \mathrm{Q}_V/\partial {k_V}^2 < 0$.

Proof of ***Corollary 3***: Because $\Delta k_V \geq \Delta k_B$, we have $k_V \geq k_B$. The comparison of (12) and (26) leads to $\mathrm{Q}_V \geq Q_B$.

Proof of ***Corollary 4*** : Because Q_V and Q_B have the same form: $\mathrm{Q} = \frac{N(a-c)}{2(N+1)(b+\gamma/\mathrm{k})}$, we have $\mathrm{d} = \frac{Q}{k} = \frac{N(a-c)}{2(N+1)(bk+\gamma)}$. Because $k_V \geq k_B$, we obtain $d_V \leq d_B$.