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Capacity investment size and timing in a port under uncertainty and congestion

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CONTENTS

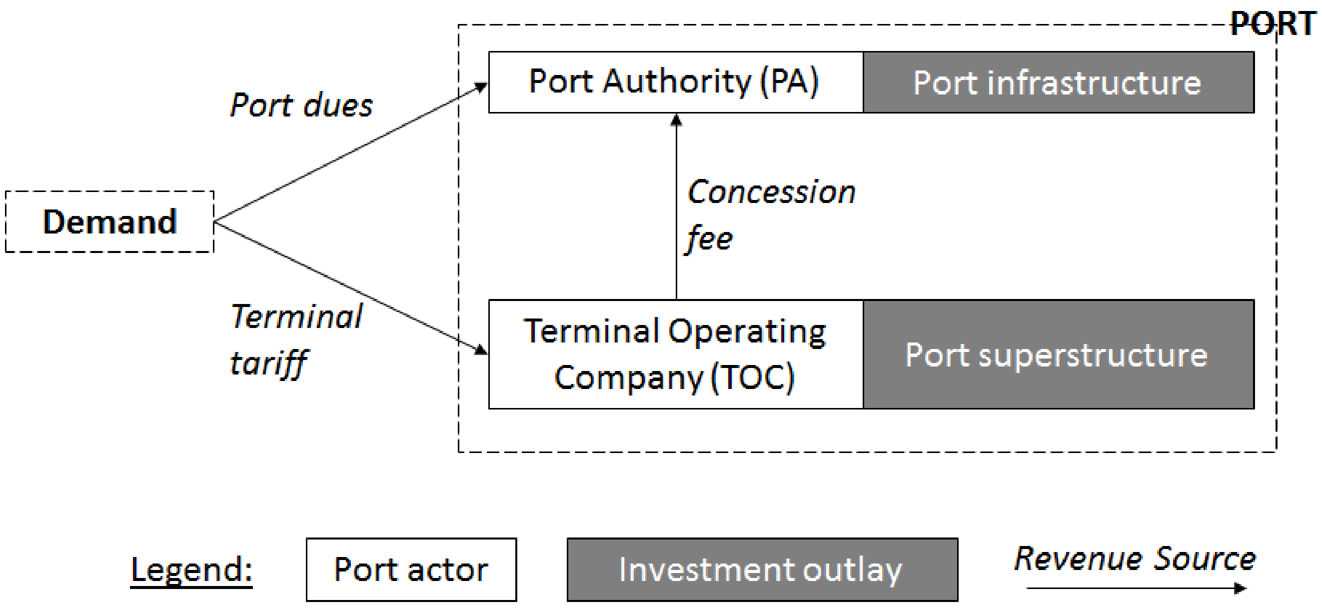
Introduction and Problem description (1)

- Investments in port capacity:
  - Focus on infrastructure (superstructure needed too)
  - Uncertainty: focus on demand uncertainty
  - Irreversible
  - Large sums of money

- The context:
  - One single investment in new capacity (no expansion)

INTRODUCTION AND PROBLEM DESCRIPTION (2)

- Port structure:
  - PA vs TOC
  - Privately vs Publically held



Introduction and Problem description (3)

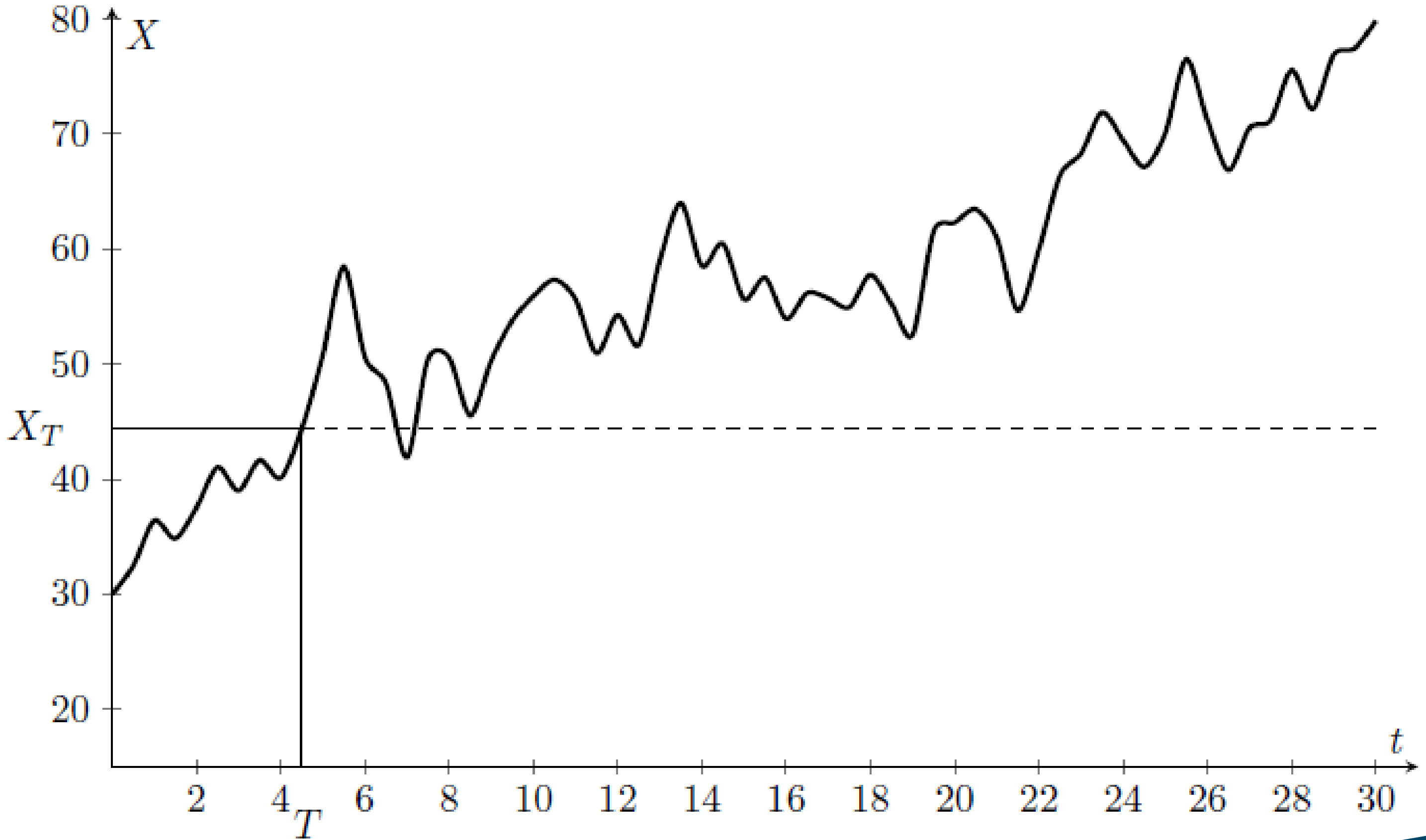
- Trade-off in port capacity
  - Undercapacity: waiting times ~ congestion cost
  - Overcapacity: too high investment cost

METHODOLOGY (1)

- Real options to valuate flexibility:
  - Size and timing of investment
  - Output flexibility

Methodology (2)

- Price: $p(t) = X(t) - Bq(t)$: X = intercept, q = throughput
- GBM for *X* (timing parameter): $dX(t) = \mu X(t)dt + \sigma X(t)dZ(t)$



METHODOLOGY (3)

- Model includes congestion cost: $A \frac{X}{B} \left(\frac{q}{K} \right)^2$
  (adds to literature)

- K = total capacity
- q/K = occupation rate
- X/B = maximal demanded throughput
- A = monetary scaling factor (expression of aversion to waiting time)

METHODOLOGY (4)

- Multiple actors:
  - Split income, operational and investment cost between PA and TOC with shares
  - Concession fee = % of TOC operational π

- Public PA:

Local benefits $LB = \pi_{PA} + \lambda q$

$$\lambda (= 0.4) \quad = \quad \text{spillover benefit per unit } q$$

Social Welfare $SW = LB + CS$

$$CS \quad = \quad \text{consumer surplus, i.c. } Bq^2/2$$

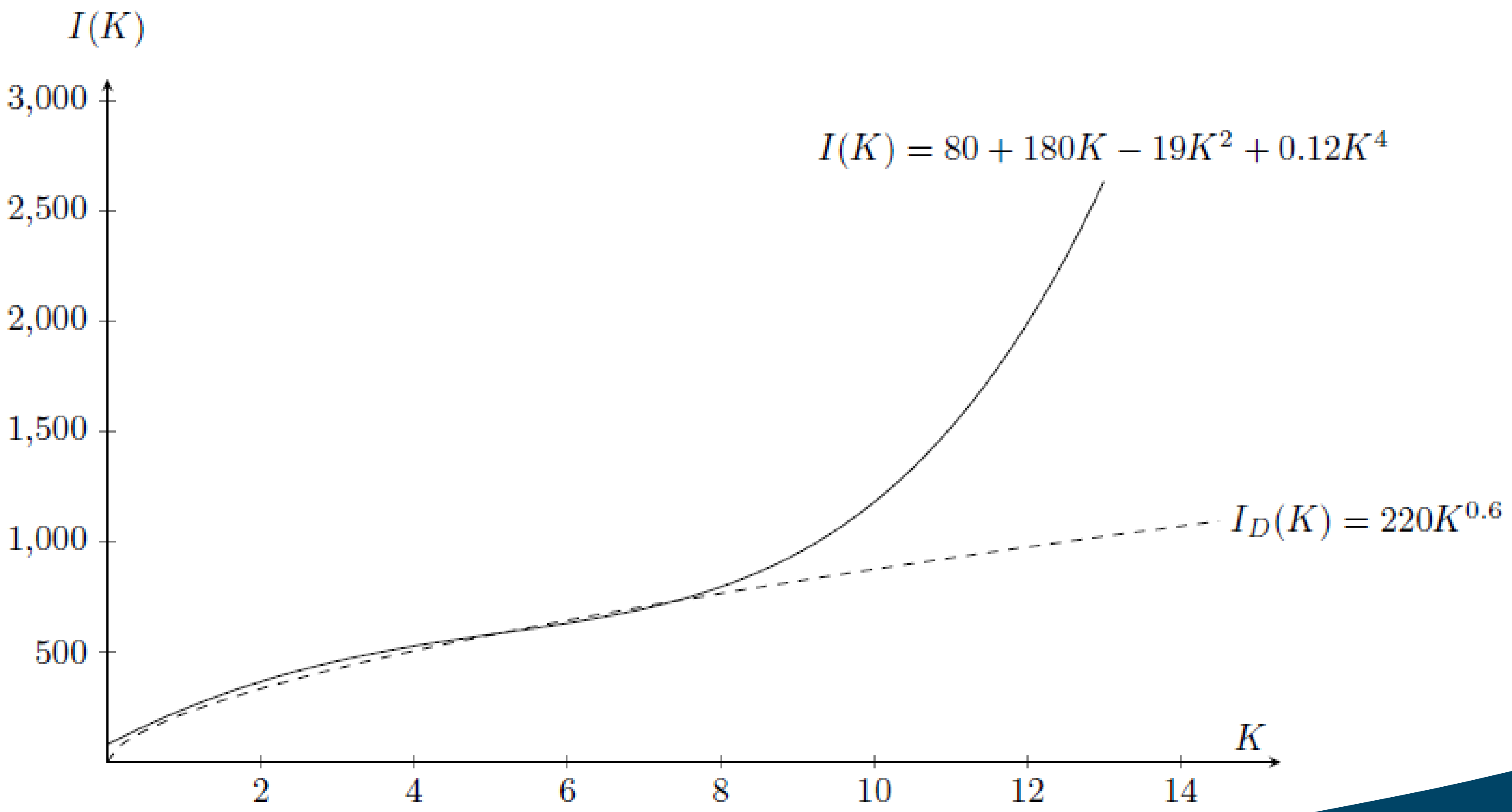
PA objective function $\Pi_{PA} = (1 - s_L - s_G) \cdot \pi_{PA} + s_L \cdot LB + s_G \cdot SW$

$$s_L (\in [0;1]) \quad = \quad \text{share of PA owned by local government}$$

$$s_G (\in [0;1]) \quad = \quad \text{share of PA owned by central government}$$

METHODOLOGY (5)

- Investment function: economies of scale + boundary



METHODOLOGY (6)

- Optimal *q* as a function of *X*(+) and *K*(+), *K* is upper limit

- Dynamic programming:
  - Bellman equation and Itô’s Lemma:
  - Find discounted sum of cash flows = project value

METHODOLOGY (7)

- Maximising the option to find optimal *X(K/+)*:

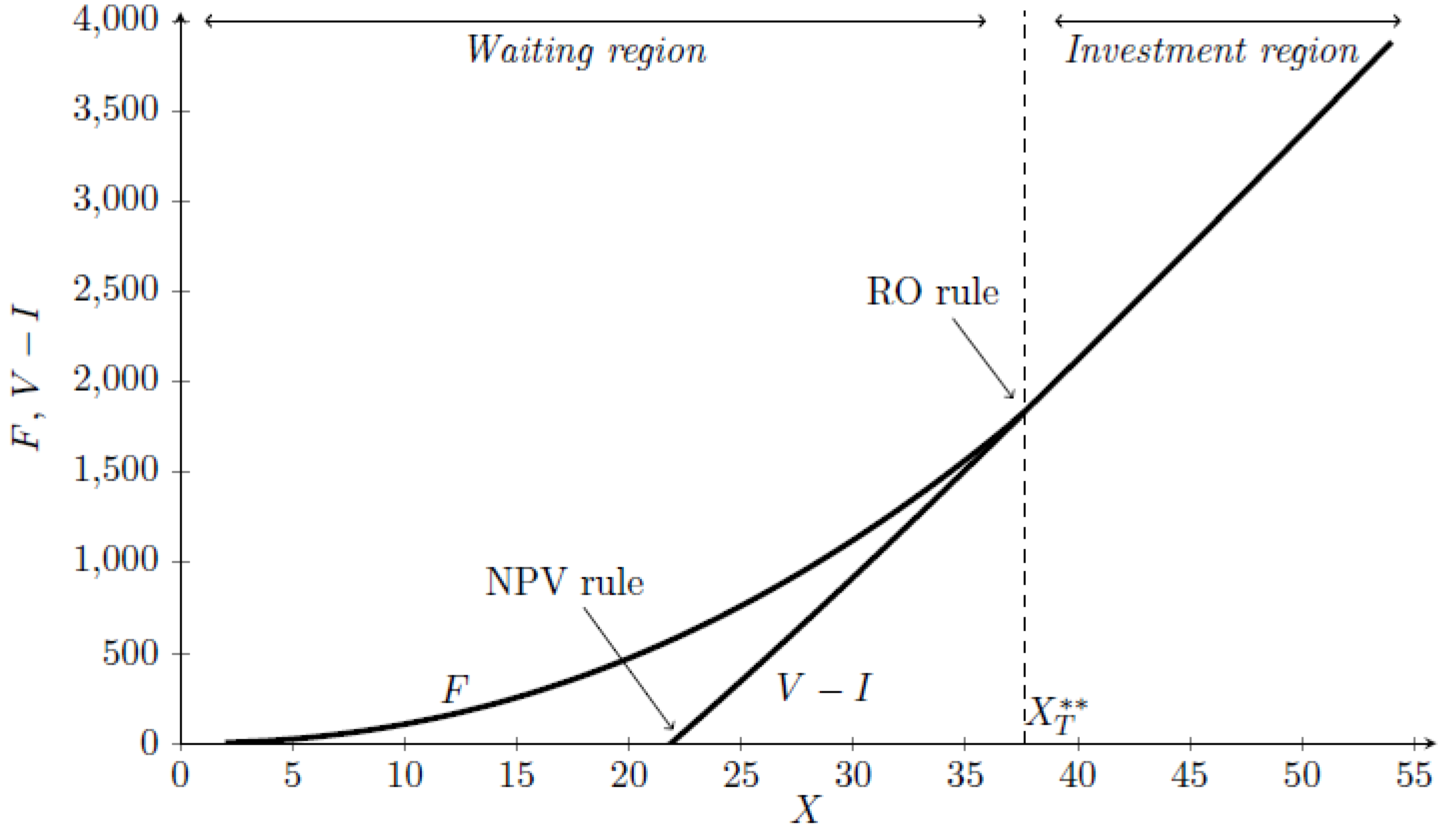
$$F(X) = \max\{e^{-rdt}\mathbb{E}(F(X) + dF(X)), \max_K [V(X,K) - I(K)]\}$$

- Optimal *K(X/+)*: $v(X,K) - \frac{dI(K)}{dK} = 0$

- Joint optimum:
    - Timing (X, threshold) and size (K, capacity)

METHODOLOGY (8)

- RO output graphically



METHODOLOGY (9)

- Stepwise approach for TOC and PA:
  1. *Find q^{opt} for TOC (determines throughput)*
  2. *Find project V for TOC*
  3. *Option value: (X, K) for TOC*
  4. *Find project V for PA (taking q^{opt})*
  5. *Option value: (X, K) for PA*
  6. *Determine or negotiate joint decision*

RESULTS (1)

- Positive relationship between size and timing
- More demand uncertainty: Bigger, Later investment
- Higher cost of congestion: idem
- Higher operational and investment cost: idem
- Higher economic growth: idem
- More public money involved: Earlier investment

RESULTS (2)

- TOC and PA may have different optimal investment

- Uniform decision required (concession agreement)
  - ➢ Negotiation interval
  - ➢ Negotiation power

- Concession fee has an impact:
  - ➢ Low fee? (PA: later + more,) TOC: earlier + less
  - ➢ Fee equaling size or timing of both actors
  - ➢ 2 PA strategies (negotiate or force)

Conclusions and Future research

- Impact of uncertainty
- The role of congestion aversion in a port
- Multiple actors and owners

- Expand models:
  - Competition (Game theory)
  - Port expansion and Time to build
  - Phased investment

Thank you for your attention!
Questions?

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