Transport Investment Regulatory Policy

Can we improve on the current uncoordinated decision game played on an unequal playing field?

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Arthur Grimes
Senior Fellow, Motu Economic & Public Policy Research
Adjunct Professor, Economics, University of Auckland

Motivation

- Major freight transport modes
  - Road
  - Rail
  - Coastal shipping
  - Also airports and broadband
- Most have govt ownership or funding
- But investment decisions are:
  - Uncoordinated; and
  - Based on different rules
- What are the sub-optimal impacts of this?

Government involvement

- Central government owns:
  - Roads
  - Rails and rolling stock
  - Some airports
  - Majority of Air NZ
- Local government owns
  - Ports (wholly or in part)
  - Some airports
- Central government funds fibre roll-out
  - i.e. a competing mode of access

Competing decision structures (1)

- **Roading investment follows a detailed NZTA CBA**
  - Takes account of private & public benefits including: agglomeration, pollution, congestion, safety, …
  - But BCR generally has to be high (>2; poss 3-4)
  - With high discount rate (7-8% p.a. real)
  - Except when there is political involvement!
  - Funded on a PAYGO basis by user levies

- **NZ Rail (KiwiRail) is an SOE**
  - SOEs are expected to make a profit
  - i.e. private rather than public benefit basis for investment decisions

Competing decision structures (2)

- **Port investment depends on the port**
  - Port of Tauranga is listed on NZX (but with sizeable passive local govt shareholding)
  - Ports of Auckland is 100% owned by local govt
  - Auckland councils rejected merger with PoT
  - Most other ports also owned by local authorities
  - Tauranga more efficient than other ports
  - Auckland decisions likely reflect political actors
- **Airports**
  - Mixture of listed (part-govt owned) & unlisted
- **Broadband rollout**
  - Politically determined

Question

- What are the effects of government policies in the provision of these rival infrastructures?
  - Given there is no single body within the 'holding company' that coordinates investment decisions across the owned (or funded) 'subsidiaries'

- Note literature on behaviour of holding companies & subsidiaries under uncertainty
  - But we will simplify to look at certainty case
    - Given that current structures not even set up for this simpler case

Outline

- Background
- 2 agent, 3 period game with externalities
  - Myopic solution
  - Nash equilibrium
  - Stackelberg equilibrium
  - Differing treatment of social returns
  - Differing minimum BCRs
- Conclusions

Background (NZ)

- Average freight travel distance = 110km
  - mostly intra-regional (e.g. within top ½ of NI)
- Road (91%), rail (7%), coastal shipping (2%)
- Building materials/fertiliser/minerals (19%), logs (16%), dairy (11%)
- Forecast volumes based on extrapolations
  - Domestic cargo could grow through to 2041 at 1.6% p.a., or 4.8%!
  - PoA could reach capacity in 2024, or post-2100!

Background (cont)

- Consultancy reports have had 4 themes:
  - Freight flow forecasts (see above)
  - Performance of freight sector
    - e.g. efficiency of individual ports
  - Policy approaches & coordination across agents (e.g. complementarity of road & rail)
    - Differences between Labour govts (more environmental concerns) & National govts (more focused on economic growth & price mechanisms)
  - Interrelationships between freight modes
    - Mostly notable by its absence (except Kim PhD)
    - This is the focus of our paper

Strategic freight interaction game

- 2 transport providers: A & B
  - A (B) can only invest in project 1 (2)
- 3 period model: t=1, 2, 3
- Each agent makes *at most* one investment
  - Either in t=1 or 2 (timing is a choice variable)
  - Investment is binary (no choice on size)
  - Returns received in period(s) after investment
- No uncertainty
- Only pure strategies considered
- Each agent's investment affects other's returns

Decision-making structure & payoffs

c_{it} is investment in project i in period t

R_{it} is return in time t to project i (may incl private & public)

		Payoff for A		Payoff for B	
		Potential cost	Return	Potential cost	Return
T=1	Invest	c_{11}	0	c_{21}	0
T=2	Invest and payoff	c_{12}	$R_{12}(c_{11}, c_{21})$ + −	c_{22}	$R_{22}(c_{11}, c_{21})$ − +
T=3	Payoff	0	$R_{13}(c_{11}, c_{21}, c_{12}, c_{22})$ + − + −	0	$R_{23}(c_{11}, c_{21}, c_{12}, c_{22})$ − + − +

Returns

- Each provider's payoff is increasing in their previous investment, and decreasing in their opponent's previous investment.
- Normalise $R_{it}(0) = 0$
- For positive investments, $R_{it}\left(c_{-i,t-1}\right) < 0 < R_{it}(c_{i,t-1})$ where $c_{-i,t-1}$ denotes the investment chosen by the other agent in period t-1.
- Each provider chooses their investment to maximise their return (measured as the BCR).

Possible outcomes

Agent B \ Agent A		No investment	Invest in t=1	Invest in t=2
No investment		I	II	III
Invest in t=1		IV	V	VI
Invest in t=2		VII	VIII	IX

Social optimum (Ŝ)

$$\hat{S} = \text{argmax}_{c^a_{11},c^a_{21},c^a_{12},c^a_{22}} \frac{\beta(R_{12}(c^a_{11},c^a_{21})+R_{22}(c^a_{11},c^a_{21}))+\beta^2(R_{13}(c^a_{11},c^a_{21},c^a_{12},c^a_{22})+R_{23}(c^a_{11},c^a_{21},c^a_{12},c^a_{22}))}{c^a_{11}+c^a_{21}+\beta(c^a_{12}+c^a_{22})}$$

s.t. $c^a_{i1} = 0$ if $c^a_{i2} > 0$, $c^a_{i2} = 0$ if $c^a_{i1} > 0$ where $i = 1,2$

where β is the discount factor;
c^a_{it} is *actual* investment by agent i in time t (either 0 or c_{it})

Myopic solution

- Each agent commits to an investment plan in t=0 (i.e. prior to t=1), ignoring their opponent's possible actions.
  - Effectively make their investment decisions under the assumption that their opponent does not invest.
  - Possibly realistic for NZ case

- Derive, in turn:
  - Conditions for A to invest in t=1 over no investment
  - A to invest in t=2 over no investment; and then, conditional on investment occurring,
  - A's timing of investment at t=1 or t=2.

Myopic solution (cont)

Derive decisions for A (B is mirror image)

In t=1, A invests (relative to no investment) iff:

$$\frac{\beta R_{12}(c_{11})+\beta^2 R_{13}(c_{11})}{c_{11}} \geq R$$

R is the required minimum rate of return

R may be greater than unity e.g. because of tax wedges and shortage of capital.

Private payoff > combined payoff

$$\underbrace{\frac{\beta R_{12}(c_{11})+\beta^2 R_{13}(c_{11})}{c_{11}}}_{\text{A's private payoff, A invests t=1}} > \underbrace{\frac{\beta\left(R_{12}(c_{11})+R_{22}(c_{11})\right)+\beta^2(R_{13}(c_{11})+R_{23}(c_{11}))}{c_{11}}}_{\text{Combined payoff, only A invests t=1}}$$

A's private payoff,
A invests t=1

Combined payoff,
only A invests t=1

Myopic solution (cont)

If c_{11}=0, A invests in t=2 (relative to none) iff:

$$\frac{\beta R_{13}(c_{12})}{c_{12}} \geq R$$

Private payoff again > combined payoff:

$$\underbrace{\frac{\beta R_{13}(c_{12})}{c_{12}}}_{\text{A's private payoff, A invests t=2}} > \underbrace{\frac{\beta (R_{13}(c_{12})+R_{23}(c_{12}))}{c_{12}}}_{\text{Combined payoff, only A invests t=2}}$$

A's private payoff, A invests t=2

Combined payoff, only A invests t=2

Myopic solution

Decision on timing to invest: t=1 or t=2

A will invest in t=1 (over t=2) iff:

$$\underbrace{\frac{\beta R_{12}(c_{11})+\beta^2 R_{13}(c_{11})}{c_{11}}}_{\text{A's private payoff, A invests t=1}} > \underbrace{\frac{\beta^2 R_{13}(c_{12})}{\beta c_{12}} \left[= \frac{\beta R_{13}(c_{12})}{c_{12}}\right]}_{\text{A's private payoff, A invests t=2}} \qquad (5)$$

A's private payoff, A invests t=1

A's private payoff, A invests t=2

t=1 is socially optimal timing (if only A should invest) iff:

$$\underbrace{\frac{\beta R_{12}(c_{11})+\beta^2 R_{13}(c_{11})}{c_{11}}}_{\text{A's private payoff, invest t=1}} + \underbrace{\underbrace{\frac{\beta R_{22}(c_{11})+\beta^2 R_{23}(c_{11})}{c_{11}}}_{\text{Cost to B if A invests t=1 (term<0)}} - \underbrace{\frac{R_{23}(c_{12})}{c_{12}}}_{\text{Cost to B if A invests t=2 (term<0)}}}_{\text{Difference in externalities. Sign ambiguous}} > \underbrace{\frac{\beta R_{13}(c_{12})}{c_{12}}}_{\text{A's private payoff, invest t=2}} \qquad (7)$$

A's private payoff, invest t=1

Cost to B if A invests t=1 (term<0)

Cost to B if A invests t=2 (term<0)

A's private payoff, invest t=2

Difference in externalities. Sign ambiguous

Myopic solution comment

- Each agent ignores the negative impact of their investment on other transport providers
- May result in over-investment by the agent
- In addition, timing of investment may be sub-optimal

Nash solution

- Paper goes through same process for the other 2 rows of Table 2
- Same insights:
  - Possible over-investment by A
  - Possible mis-timing of investment

Nash equilibrium example (BCRs)

A: 1st row; B: 2nd row; Social: 3rd row

Over-investment occurs (Same result occurs with myopic approach)

Nash equilibrium

Agent B \ Agent A	No investment	Invest in t=1	Invest in t=2
No investment	- - -	1.3 - 1.3	1.2 - 1.2
Invest in t=1	- 2.9 2.9	1.2 1.4 1.3	1.1 1.3 1.2
Invest in t=2	- 1.6 1.6	1.3 1.1 1.2	1.2 1.0 1.1

Social optimum

Stackelberg equilibrium example

A is the leader; only 1 project, but the wrong one, is chosen

Agent B \ Agent A	No investment	Invest in t=1	Invest in t=2
No investment	- - -	1.3 - 1.3	1.2 - 1.2
Invest in t=1	- 2.9 2.9	1.2 0.8 1.0	1.1 1.3 1.2
Invest in t=2	- 1.6 1.6	1.2 0.9 1.1	1.2 1.0 1.1

Stackelberg equilibrium (annotated: Agent B No investment / Agent A Invest in t=1)

Social optimum (annotated: Agent B Invest in t=1 / Agent A No investment)

Inconsistent treatment of social returns

Use NE table; 1/3 of returns are private; 2/3 public but social planner only considers public benefits for A, not B

Effect is to choose A's project, not B's (i.e. wrong project)

Agent A / Agent B	No investment	Invest in t=1	Invest in t=2
No investment	- - -	1.3 - 1.3	1.2 - 1.2
Invest in t=1	- 1.0 1.0	1.2 0.5 0.8	1.1 0.5 0.8
Invest in t=2	- 0.5 0.5	1.3 0.4 0.9	1.2 0.3 0.7

'Wrong' social optimum

Differing minimum required BCRs

- With NE table, assume BCRs differ:
  - agent A has minimum required BCR of 1
  - agent B has minimum required BCR of 3
- Agent A will invest in t=1
- Agent B will not invest

Conclusions

- Model & examples chosen to reflect NZ transport planning approaches including:
  - – Lack of coordination across modes
  - – Differing treatment of public returns
  - – Differing BCRs
  - – Potential Stackelberg leader role for roads
- Sub-optimal effects include:
  - – Over-investment by some agents
  - – Wrong investments
  - – Mis-timed investments

Final comments

- Govt owns or controls many aspects of transport system
- Frequently, the investments are long-term (e.g. many decades) and are very costly (billions of dollars)
- Paper makes no judgement as to which investments are favoured overall
- But current system is likely to result in sub-optimal infrastructure choices