INVESTMENTS NEEDS FOR TRANSPORT INFRASTRUCTURES ALONG LOW CARBON PATHWAYS

Summer School - CIRED
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Co authored with Céline Guivarch
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MOTIVATION
Transport sector and infrastructures

- Immobile capital (Prud’homme, 2004)
- Long lifetime (Prud’homme, 2004)
- ‘Lumpy’ investments (Lecocq et al, 2014)
- Increasing returns to scale (Driscoll, 2014)
A role to play in sustainable development

Population and economic growth → Higher freight and passenger activity

- 23% of energy-related CO₂ emissions (IEA, 2017)
- Highest GHG emissions growth since 1970 (IEA, 2012)

Balancing mobility demand

Increasing stocks + maintenance

Mitigation

Modal shift (Henao, 2015)
Lock-in (Guivarch et al, 2011)
Chronic underinvestment?

“The engineers estimated the cost of bringing America’s infrastructure to a state of good by 2020 at $3.6 trillion, **of which only about 55 percent has been committed.**” (ASCE, 2013)

“...the transport infrastructure gap in Latin America will once again **increase**, which could seriously limit the total volume traded” (Campos & Gaya, 2009)

“Years of **chronic underinvestment** in critical areas such as transportation [...] are now catching up with countries around the world.” (McKinsey, 2013)

→ Tension exacerbated or released?
Research questions

*Impacts of climate policies on investments needs of transports infrastructure*

Regional heterogeneity?  
Costs Determinants?  
Avoiding pathways with high investments risks?
# Literature review

<table>
<thead>
<tr>
<th>Literature</th>
<th>Period</th>
<th>Infrastructures</th>
<th>Results</th>
<th>Low carbon</th>
<th>O&amp;M costs</th>
<th>% of GDP</th>
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<td>Dobbs (2013)</td>
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## Gaps addressed

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<td>Our study</td>
<td>2100</td>
<td>Road, rail, BRT, HSR</td>
<td>?</td>
<td>X</td>
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+ Regional and Global scale results
METHODOLOGY

1. Construction socio-economic scenarios
2. Quantifying ‘ex-post’ investments needs
The IMACLIM-R model (Waisman et al, 2013)

- Hybrid model: CGE + bottom up modules
- Recursive dynamic architecture
- 12 sectors, 12 regions $\rightarrow$ 5 regions (ASIA, CIS, LAM, OECD, MAF)
- Second best worlds

Passenger:
- Mobility services in utility function
- Time and budget constraints

Freight:
- I/O coefficients
## Uncertainties on mobility patterns

<table>
<thead>
<tr>
<th>Sets of parameters (each set may include dozens of technical parameters)</th>
<th>Alternatives</th>
</tr>
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<tr>
<td>Demography and productivity</td>
<td>SSP1, SSP2 or SSP3</td>
</tr>
<tr>
<td>Determinants of mitigation challenge (fossil fuels reserves and markets, energy demand, low carbon technologies for all sectors except transport)</td>
<td>low or high challenges</td>
</tr>
</tbody>
</table>

### Transport sectors parameters

| Affluence: I/O freight coeff, household budget share allocated to transport | low or high transport demand |
| Structure: motorization rate, car occupancy, congestion | individual mobility dominated evolution or shared-mobility oriented evolution |
| Intensity (energy efficiency) | Low or high energy efficiency |
| Fuel (alternative fuels) | Low or high availability of biofuels |
Climates policies in Imaclim-R

Between RCP 2.6 and RCP 4.5
METHODOLOGY

1. Construction socio-economic scenarios
2. Quantifying ‘ex-post’ investments needs
Investments needs module

- Dissagregation of mobility scenarios
- Aggregation on the different infrastructures
- Calculation of infrastructure needs at each time step
- Associated costs
Investments needs module

+ Dissagregation of mobility scenarios
  • *Passenger*: car, air and other terrestrial transportation → BRT, rail, bus, high-speed rail
  • *Freight*: terrestrial → train and truck

- Aggregation on the different infrastructures
- Calculation of infrastructure needs at each time step
- Associated costs
Investments needs module

- Dissagregation of mobility scenarios
+ Aggregation on the different infrastructures
  • Rail : pkm+tkm on track.km
  • Road : vkm on lane.km (occupancy factors)
  • BRT lanes : pkm on trunk.km
  • HSR : pkm on track.km
- Calculation of infrastructure needs at each time step
- Associated costs
Investments needs module

- Dissagregation of mobility scenarios
- Aggregation on the different infrastructures

+ Calculation of infrastructure needs at each time step
  • Target of infrastructure utilisation level reached in a certain delay
  • Ideal utilisation rate compared to real one each year
  • Constraint on infrastructures density

- Associated costs
Investments needs module

- Dissagregation of mobility scenarios
- Aggregation on the different infrastructures
- Calculation of infrastructure needs at each time step

+ Associated costs
  • New builds + maintenance and upgrade (depends on the stock)
  • Costs per pkm for airports
  • Analysis with outputs from Imaclim (GDP, CO₂ emissions)
Uncertainties again...

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<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
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<td>Past trend</td>
<td>Modal shift</td>
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- 5% of bus mobility as BRT (Dulac, 2013)
- Rail freight share 50% greater than road in 2050 (UIC, 2016)
- Rail passenger share represents 40% of public transport in 2050 (IEA, 2012)
### Uncertainties again...

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<td><strong>“desirable” level of road utilization rate</strong></td>
<td>300 thousand vkm/paved lane.km</td>
<td>600 thousand vkm/paved lane-km</td>
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Road utilisation rate in average on the period 2000-2010 – Dulac(2013)
## Investments needs module

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</tr>
<tr>
<td><strong>“desirable” level of rail utilization rate</strong></td>
<td>5 million pkm-tkm/track-km</td>
<td>30 million pkm-tkm/track-km</td>
<td></td>
</tr>
<tr>
<td><strong>Delays to reach “desirable” levels of infrastructure utilization rates</strong></td>
<td>35 years</td>
<td>65 years</td>
<td></td>
</tr>
<tr>
<td><strong>Evolution in unit cost for roads</strong></td>
<td>Increase 50%</td>
<td>Constant</td>
<td>Decrease 50%</td>
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PRELIMINARY
RESULTS
Transport pathways from Imaclim-R

Freight activity over time

Passenger activity over time
Annual investment needs at global/regional scale

- Baselines
- Low mitigation ambitions
- High mitigation ambitions

% of GDP

WORLD  ASIA  CIS  LAM  MAF  OCDE
Annual investment needs at global/regional scale:

- Baselines
- Low mitigation ambitions
- High mitigation ambitions

<table>
<thead>
<tr>
<th>Region</th>
<th>Baselines</th>
<th>Low Mitigation</th>
<th>High Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>WORLD</td>
<td>2%</td>
<td>+10%</td>
<td>-4%</td>
</tr>
<tr>
<td>ASIA</td>
<td>2.5%</td>
<td>+27%</td>
<td>-5%</td>
</tr>
<tr>
<td>CIS</td>
<td>3%</td>
<td>+16%</td>
<td>-12%</td>
</tr>
<tr>
<td>LAM</td>
<td>3.5%</td>
<td>+9%</td>
<td>-2.5%</td>
</tr>
<tr>
<td>MAF</td>
<td>4%</td>
<td>-5%</td>
<td>-12%</td>
</tr>
<tr>
<td>OCDE</td>
<td>2.5%</td>
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Structural heterogeneity on transport system

<table>
<thead>
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<tr>
<td>Road utilisation rate in 2015 (thousand vkm/lane km)</td>
<td>200</td>
<td>300</td>
<td>900</td>
<td>1500</td>
<td>550</td>
</tr>
<tr>
<td>Rail utilisation rate in 2015 (thousand pkm+tkm/track km)</td>
<td>20000</td>
<td>25000</td>
<td>10000</td>
<td>6000</td>
<td>6000</td>
</tr>
<tr>
<td>Land freight intensity squared (tkm per US$2005)</td>
<td>0.66</td>
<td>1.63</td>
<td>0.63</td>
<td>0.39</td>
<td>1.66</td>
</tr>
<tr>
<td>Land passenger intensity (pkm per US$2005)</td>
<td>0.67</td>
<td>0.51</td>
<td>0.73</td>
<td>0.62</td>
<td>0.2</td>
</tr>
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Next step: Avoiding pathways with high investments needs

Figure 1: Historical annual investments on transport infrastructures (rail, road and airports) - median (solid line) and 10th and 90th percentile (dashed lines) - Data aggregated by the authors from OECD (2017) and World Bank (2017)
The desirable world
Costs determinants analysis

Analysis of variance for the different regions
Preliminary conclusions

• Similar levels of global investments needs of T.I with and without climate policy implementation
• Difference between regions in terms of...
  ➢ Investments needs
  ➢ Impacts of climate policies on investments
• Structure of transport structure as the main expansion?
• Policy/R&D to impact utilisation level of infrastructure?

• Limitations
  ➢ Macroeconomic impacts of investments
  ➢ High utilisation level of infrastructures ➔ effects on maintenance costs? Externalities and congestion?
  ➢ Ports infrastructures? Electric vehicles infra?
  ➢ Impacts on infrastructures?
Questions?