

Modeling Transportation in Input-output LCA: Challenges and Solutions

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Outline

- Introduction
- Transportation in IO-LCA: typical treatment
- Uncertainty typology for transport in IO
- Uncertainty Quantification (1997, US)
- Hybrid modeling possibilities
- Case studies
 - Automobile Manufacturing
 - Food-Miles

Introduction

- ❁ Recent Proliferation of Input-Output Analysis (IOA, IO-LCA) for LCA
- ❁ Uncertainty analysis in LCA still in infancy, especially for IO-LCA and hybrid LCA
- ❁ While IOA offers advantages, uncertainties are important to understand
- ❁ Transportation (passenger and freight) important sector for many environmental indicators

Transport in IOA

	Agriculture	Manufacture	Transport/ Services	Final Demand	Total output
Agriculture	z11	z12	z13	y1	x1
Manufacture	z21	z22	z23	y2	x2
Transport/Ser vices	z31	z32	z33	y3	x3
Value-Added	v1	v2	v3		

Transport in Different IO Tables

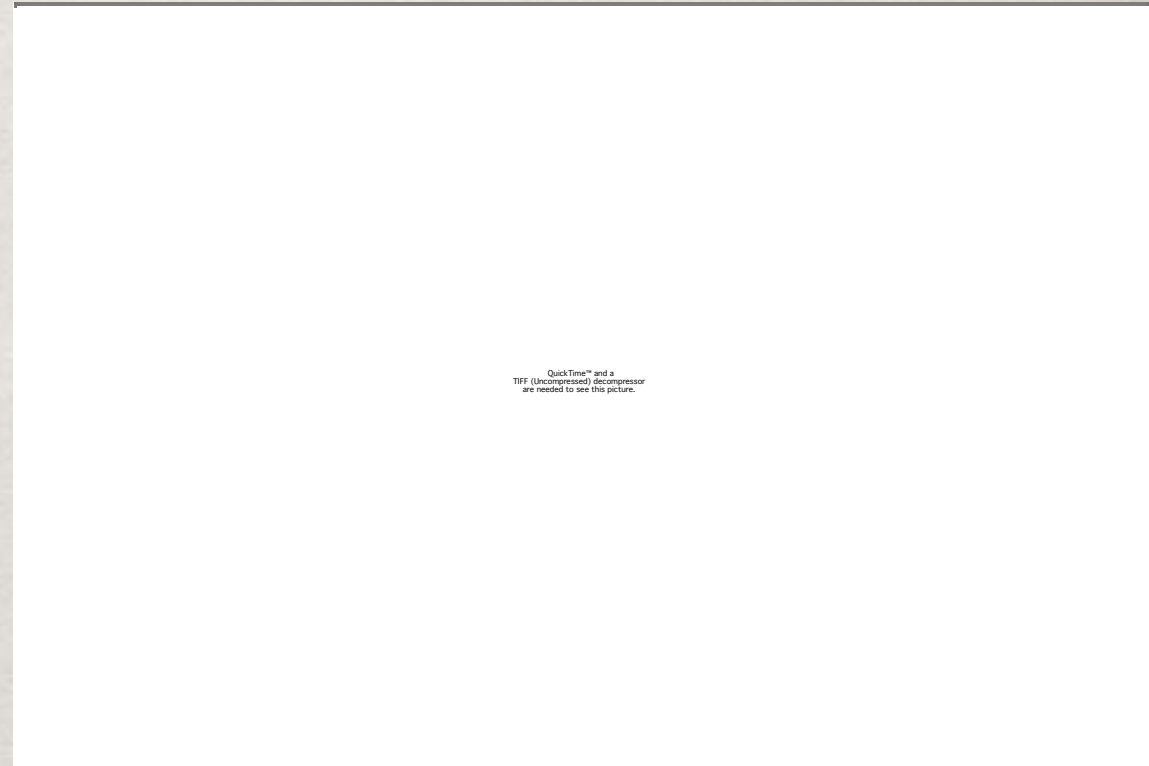
US Benchmark IOT, 1997	EU NAMEA	China IOT, 2002
Air transportation	Land Transport	Rail Passenger
Rail transportation	Water Transport	Rail Freight
Water transportation	Air Transport	Road Transport
Truck transportation	Support and Auxiliary	Water Freight and Passenger
Transit and ground passenger transportation	Post and Telecomm	Public Transport
Pipeline transportation		Air Passenger
Scenic and sightseeing transportation and support		Air Freight
Postal service		Pipeline Transport
Couriers and messengers		Post

Types of Uncertainty for Transport in IO-LCA

- Aggregation issues
 - Between transport sectors
 - Between passenger/freight
 - Between other sectors (users of transport)
- Cost/Price Uncertainty
 - Are monetary units appropriate to model transport?
- Final delivery vs. intermediate transport
- Neglect of international transport

Aggregation of Energy Profiles

- Past literature shows that different modes have different energy profiles
- Collected data from various sources in US to compare for 1997
 - Transportation Energy Databook
 - Commodity Flow Survey
 - Input-Output Accounts

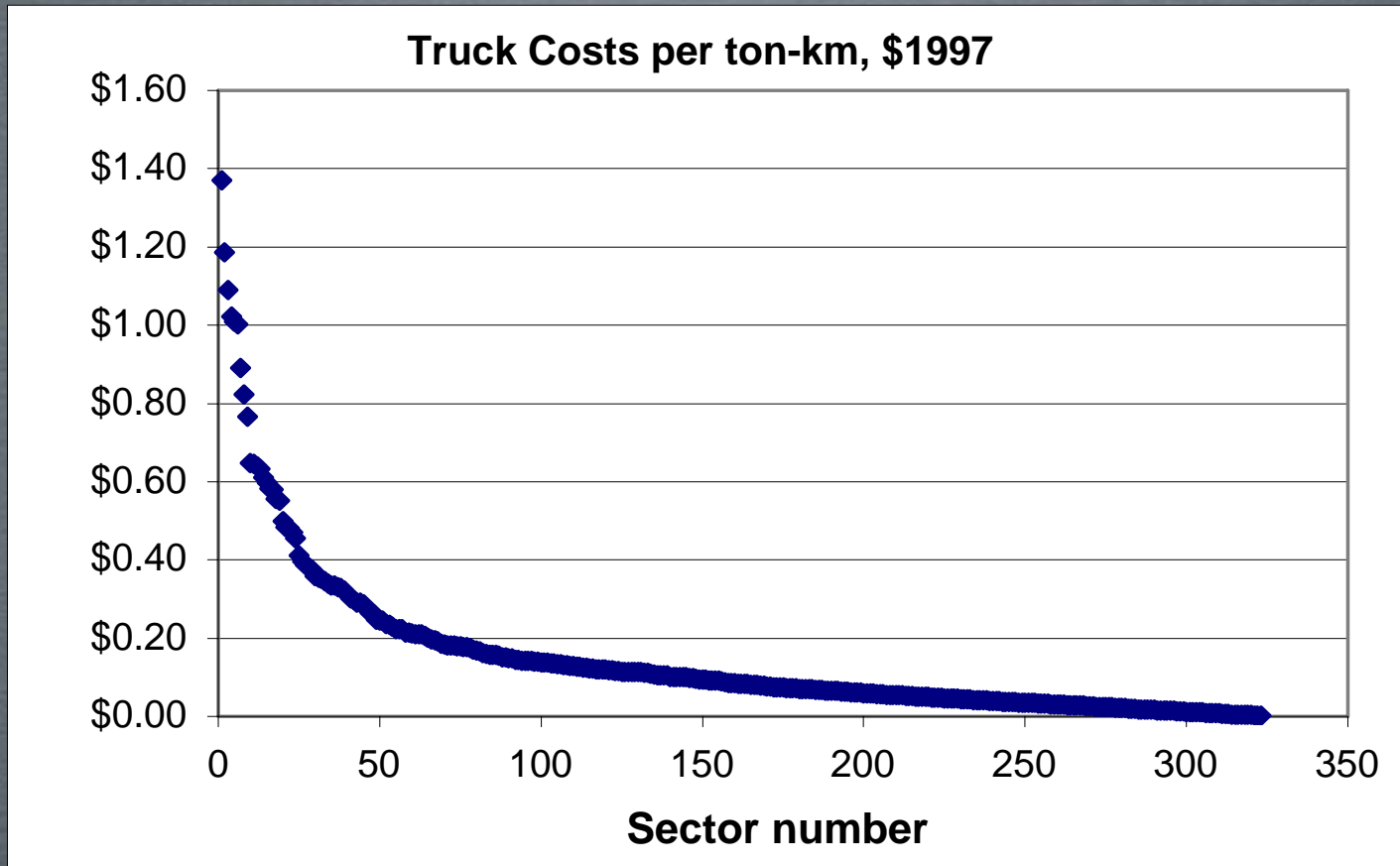


Energy Intensity Aggregation

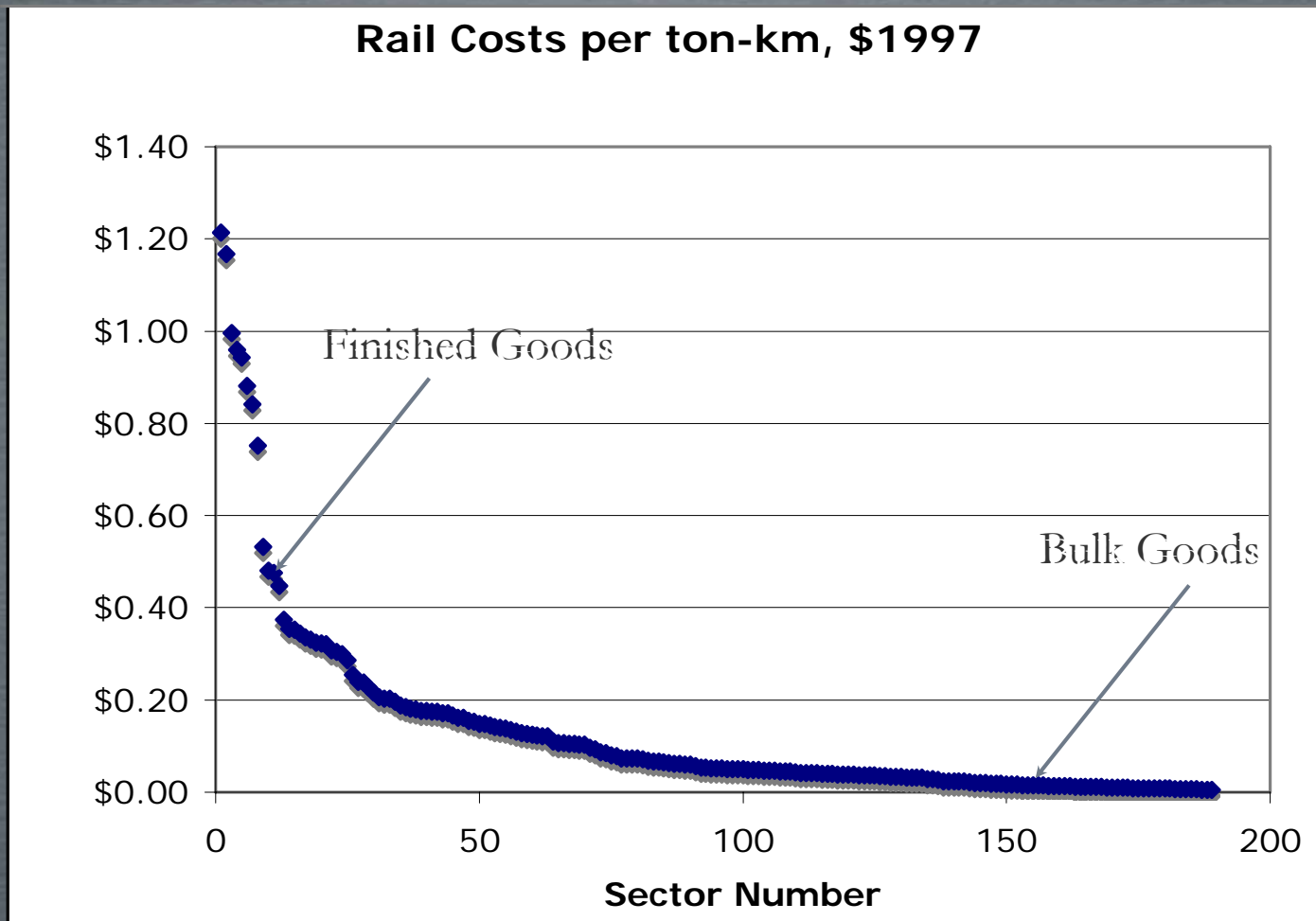
	TJ/\$M	MJ/ton-km,p-km
Gas Pipeline	42.9	2.51
oil pipeline	30.7	0.34
Air passenger, dom	30.1	4.22
Truck freight	26.6	3.88
Water freight	15.6	0.44
Rail passenger	14.7	1.27
Rail freight	14.2	0.38
Air passenger, intl	12.0	4.22
Air freight	6.7	14.6
Water passenger	data not available	
Average	21.5	3.7
Standard Deviation	11.7	5.5

Cost Aggregation

- ✿ Each sector (and final user) of the economy might spend different amounts on freight and passenger transport
- ✿ Compared estimated transport costs in input-output table to physical unit ton-km from commodity flow survey



Cost Aggregation Results:
Truck



Cost Aggregation Results: Rail

Solution: Mixed-unit IO-LCA

- Disaggregate transport sectors into freight and passenger and using physical units (where possible)
- Commodity technology allows final delivery and intermediate transport
- More informative and more accurate than standard IOA
- Allows total supply chain delineation of freight requirements (including international transport for imports)

Sample Results: Total Freight for Automobile

Total Domestic: 1.20E6 tonne-km, input: \$1M

Path	Branch	% of total				
1	0	8.9	Automobile and light truck manufacturing			
2	1	6.7	Automobile and light truck manufacturing	Motor vehicle parts manufacturing		
3	2	5.2	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Iron and steel mills	
4	3	3.6	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Iron and steel mills	Scrap
5	3	2.7	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Iron and steel mills	Iron ore mining
6	3	2.5	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Iron and steel mills	Coal mining
7	3	1.4	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Ferrous metal foundaries	Scrap
8	3	0.8	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Iron and steel mills	Iron and steel mills
9	2	0.8	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Ferrous metal foundaries	
10	1	0.7	Automobile and light truck manufacturing	Glass and glass products, except glass		

Sample Results: Total Freight for Automobile

Total International: 2.79E6 tonne-km, input: \$1M

Path	Branch	% of total				
1	0	10.5	Automobile and light truck manufacturing			
2	2	8.0	Automobile and light truck manufacturing	Motor vehicle parts	Iron and steel mills	
3	1	5.5	Automobile and light truck manufacturing	Motor vehicle parts		
4	3	2.8	Automobile and light truck manufacturing	Motor vehicle parts	Iron and steel mills	Iron ore mining
5	3	1.8	Automobile and light truck manufacturing	Motor vehicle parts	Iron and steel mills	Scrap
6	3	1.3	Automobile and light truck manufacturing	Motor vehicle parts	Iron and steel mills	Iron and steel mills
7	3	1.2	Automobile and light truck manufacturing	Motor vehicle parts	Iron and steel mills	Coal mining
8	2	1.0	Automobile and light truck manufacturing	Motor vehicle parts	Gold, silver, and other metal ore mining	
9	3	0.8	Automobile and light truck manufacturing	Truck transportation	Petroleum refineries	Disagg Oil
10	3	0.8	Automobile and light truck manufacturing	Air transportation	Petroleum refineries	Disagg Oil

Sample Results: Total Freight for Automobile

Total Domestic: 2.79E6 tonne-km, input: \$1M

Path	Branch	% of total				
1	0	10.5	Automobile and light truck manufacturing			
2	2	8.0	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Iron and steel mills	
3	1	5.5	Automobile and light truck manufacturing	Motor vehicle parts manufacturing		
4	3	2.8	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Iron and steel mills	Iron ore mining
5	3	1.8	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Iron and steel mills	Scrap
6	3	1.3	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Iron and steel mills	Iron and steel mills
7	3	1.2	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Iron and steel mills	Coal mining
8	2	1.0	Automobile and light truck manufacturing	Motor vehicle parts manufacturing	Gold, silver, and other metal ore mining	
9	3	0.8	Automobile and light truck manufacturing	Truck transportation	Petroleum refineries	Disagg Oil
10	3	0.8	Automobile and light truck manufacturing	Air transportation	Petroleum refineries	Disagg Oil

Sample Results: Total Freight for Fruit Farming

Total International 4.83E6 tonne-km, input: \$1M

Path	Branch	% of total				
1	0	37.4	Fruit farming			
2	2	19.6	Fruit farming	Petroleum refineries	Disagg Oil	
3	1	3.6	Fruit farming	Petroleum refineries		
4	2	2.2	Fruit farming	Phosphatic fertilizer Pesticide and manufacturing	Other nonmetallic mineral mining	
5	2	1.6	Fruit farming	other agricultural chemical	Other nonmetallic mineral mining	
6	3	1.4	Fruit farming	manufacturing Petroleum refineries	Petroleum refineries	Disagg Oil
7	1	1.4	Fruit farming	Phosphatic fertilizer manufacturing		
8	2	1.2	Fruit farming	Agriculture and forestry support activities	Nitrogenous fertilizer manufacturing	
9	2	0.8	Fruit farming	other agricultural chemical	Other basic organic chemical manufacturing	
10	1	0.8	Fruit farming	manufacturing Fruit farming		

Summary

- ❁ Substantial uncertainty in using standard IO-LCA for freight/passenger transportation
- ❁ New method allows greater delineation and more information on the impacts of transportation in production phase