Imperial College London

Modelling Freight Mode Choice Behaviour Accounting for Supply Chain Structures and Taste Heterogeneity

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Outline

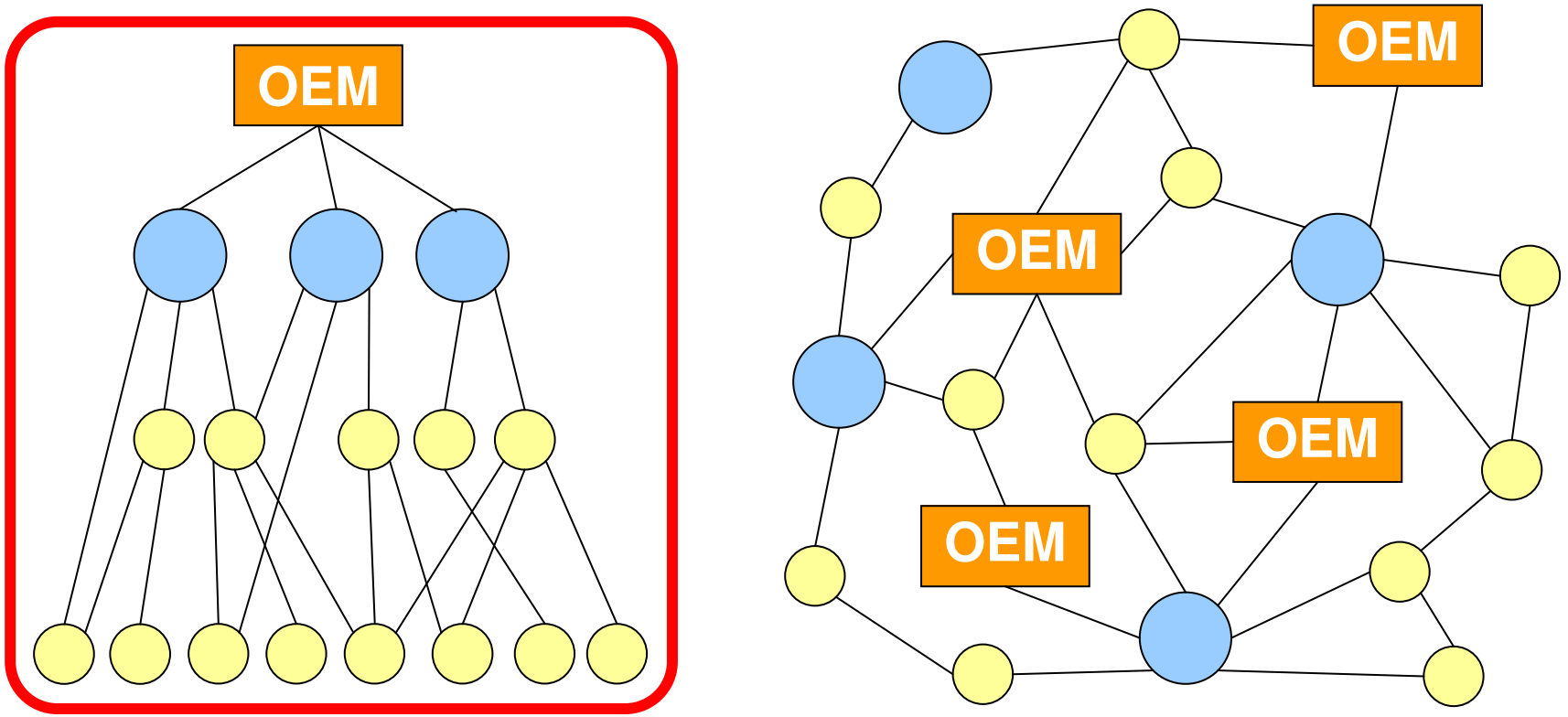
- Background
- Motivation
- Models
- Data Description
- Analysis and Results
  - Supply Chain Variables
  - Supply Chain Structures
- Conclusions

Background (1)

- Freight transport activities
- Key factors influencing the complexity of freight mode choice decisions
  - Characteristics of freight
  - Characteristics of firms
- Supply chains linking all vendors, service providers and customers

Background (2)

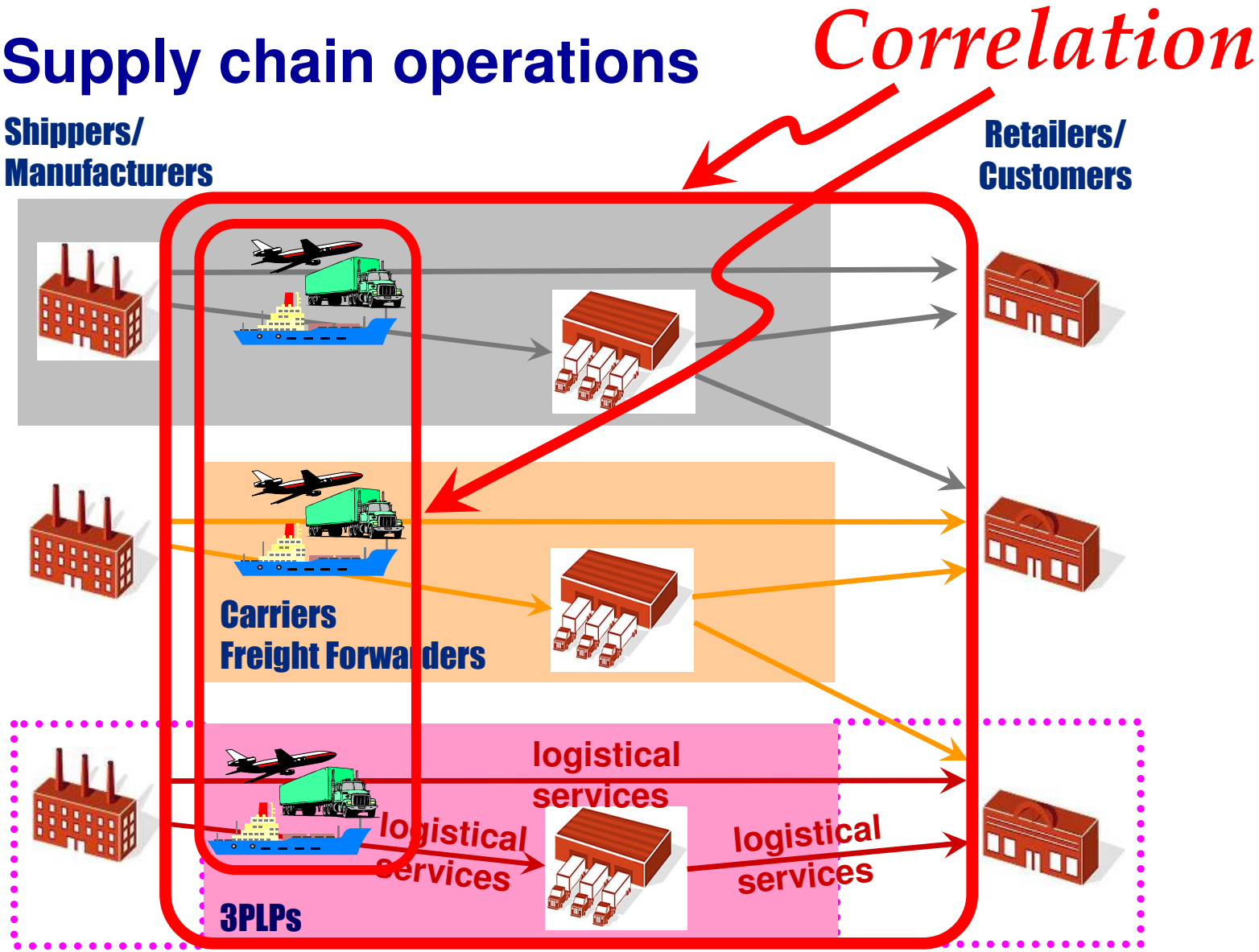
- **Supply chain relationships**



Arm's length relationship → **Full vertical integration**

Background (3)

- **Supply chain operations**



Motivation

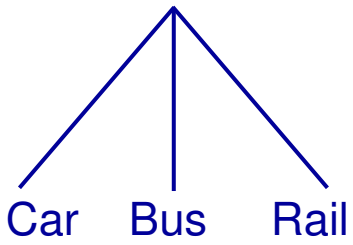
Existing modelling approaches

- **Ignore the influence of supply chain and logistics concepts**
- **Rely on conceptual and methodological approaches developed in the passenger sector**
  - Conventional logit models

Models

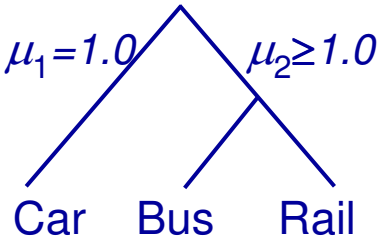
- **Generalised Extreme Value (GEV)**

$$P(a \mid C) = \frac{e^{V(a)} G_a(e^{V(1)},\ldots,e^{V(n)})}{\mu G(e^{V(1)},\ldots,e^{V(n)})} = \frac{e^{V(a)+\ln G_a(e^{V(1)},\ldots,e^{V(n)})}}{\sum_{h\in C} e^{V(h)+\ln G_h(e^{V(1)},\ldots,e^{V(n)})}}$$



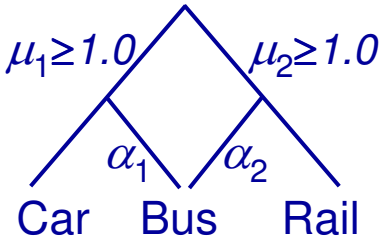
Multinomial logit (MNL)

$$G(Y_1,\ldots,Y_n) = \sum_{h\in C} Y_h^{\mu}$$



Nested logit (NL)

$$G(Y_1,\ldots,Y_n) = \sum_{k=1}^{K} \left(\sum_{h\in C_k} Y_h^{\mu_k} \right)^{\mu/\mu_k}$$

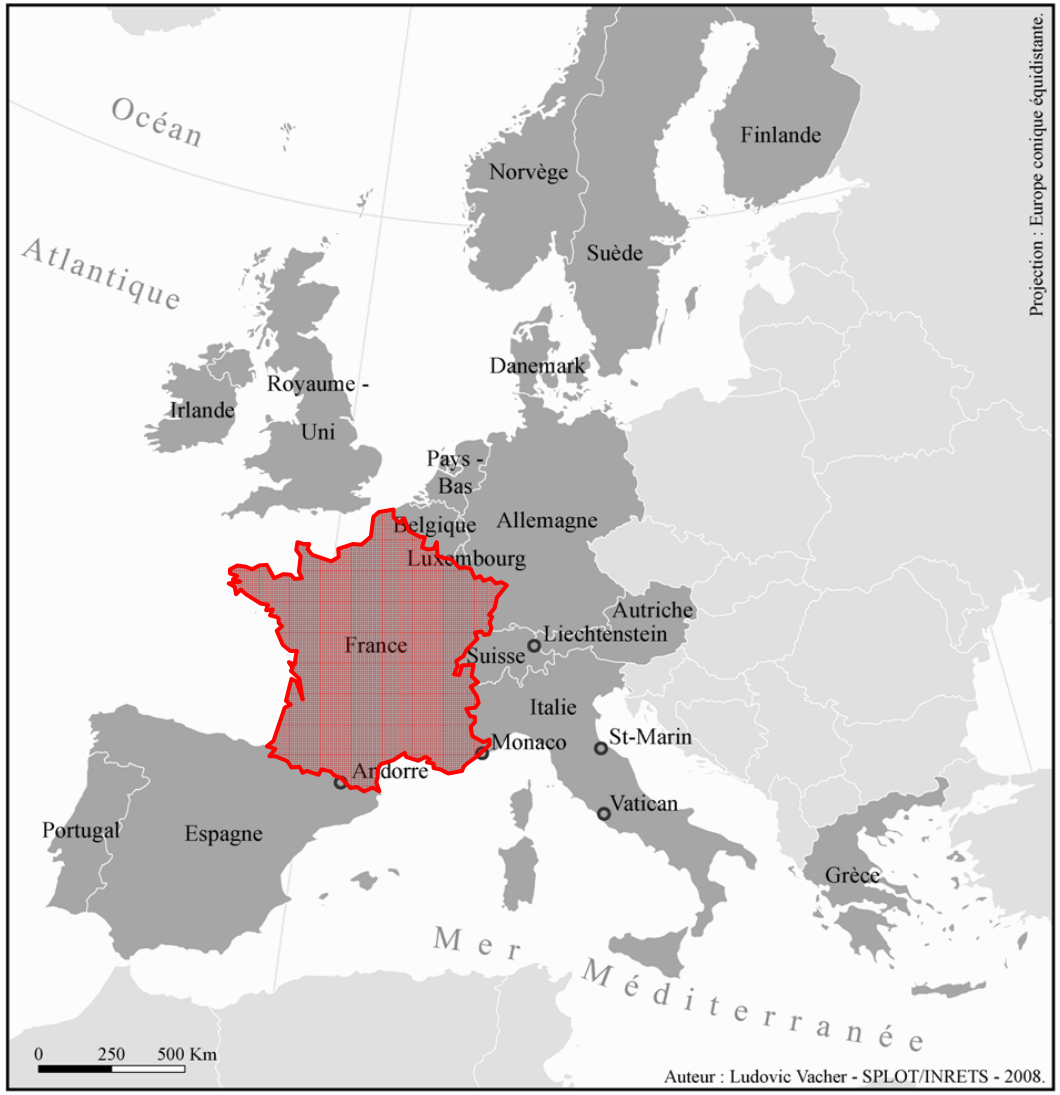


Cross-nested logit (CNL)

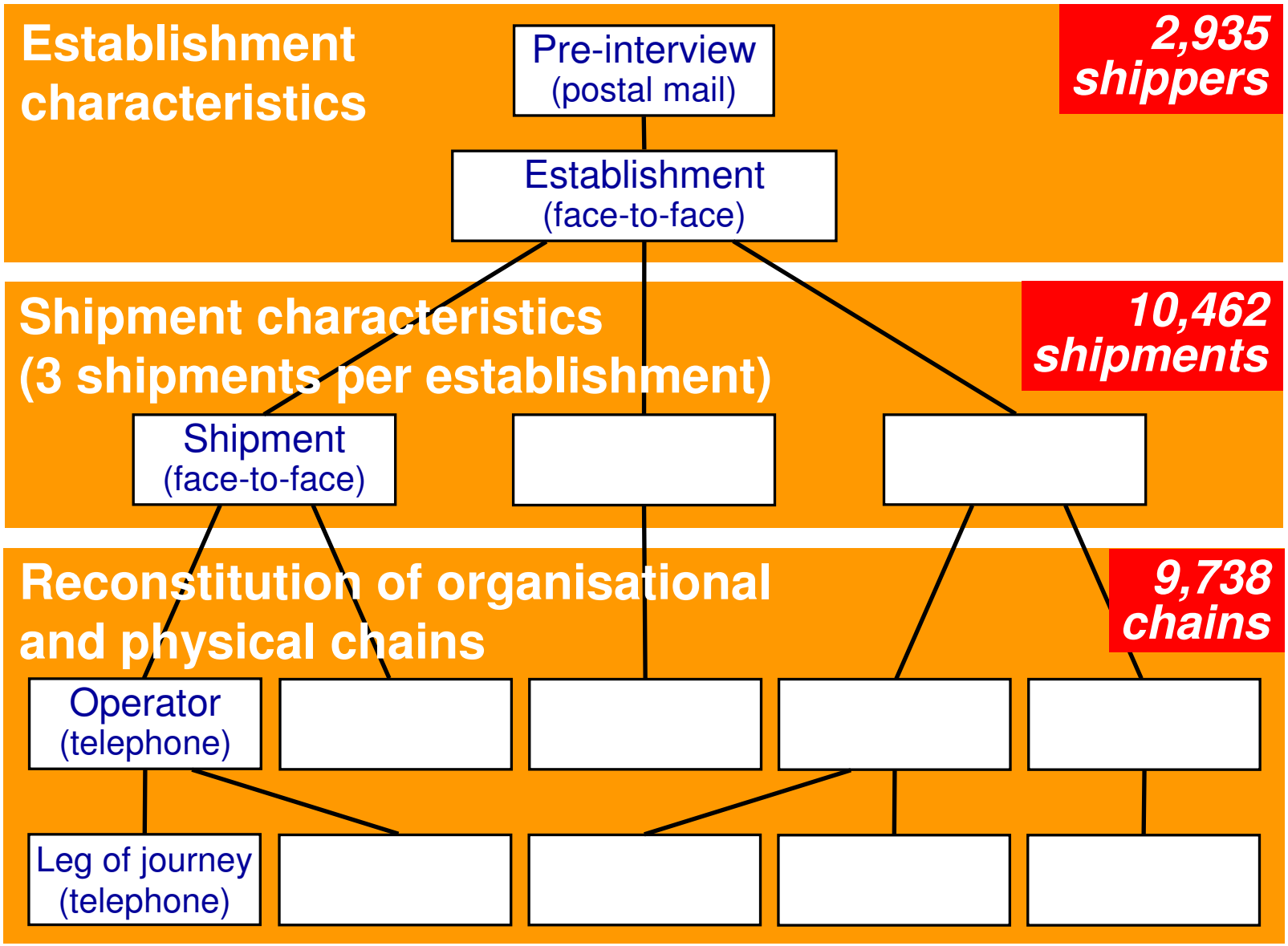
$$G(Y_1,\ldots,Y_n) = \sum_{k=1}^{K} \left(\sum_{h\in C_k} \left(\alpha_{hk}^{1/\mu} Y_h \right)^{\mu_k} \right)^{\mu/\mu_k}$$

Data Description (1)

- **2004 French shipper survey (ECHO)**



Data Description (2)



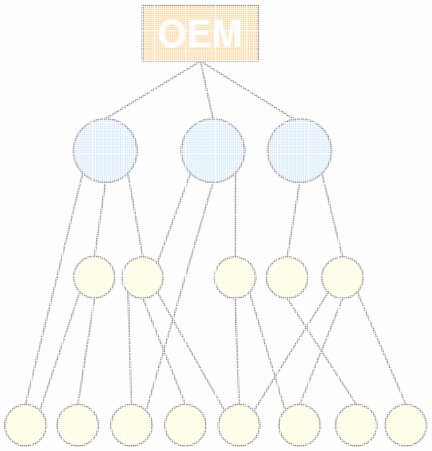
Data Description (3)

- **Level-of-service attributes**
  - Transport cost (%)
  - Travel time (hour)
  - Delay (%)
- **4 alternative land transport modes**
  - Own account road
  - For-hire road
  - Rail
  - Combined road-rail
- **542 shippers (38 business sectors)**
- **1,095 shipments (1,080 completed chains)**
- **Variables relating to shipper, shipment and flow characteristics**

Analysis and Results

- **Supply chain variables**
  - Unobserved correlation amongst different modes
  - Degree of closeness (e.g. type of contract)

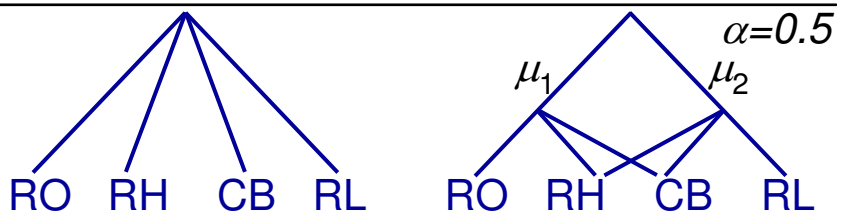
- **Supply chain structures**
  - Unobserved correlation along two choice dimensions: transport mode and supply chain



Supply Chain Variables

Basic specification

- CNL leads to an improvement in terms of model fit over MNL
- There is a significant amount of correlation amongst alternatives
- MNL underestimates the value of cost-time trade-off



Attributes	MNL Value	MNL t-test	CNL Value	CNL t-test
For-hire road	-0.3528	-3.67	-0.1722	-1.81
Rail	1.5880	2.94	1.5853	3.49
Combined	0.6501	2.29	0.5833	2.73
Cost (%)	-0.0741	-11.93	-0.0550	-9.12
Time (hr)	-0.0182	-3.95	-0.0154	-4.41
Delay (%)	-0.0078	-1.33	-0.0062	-1.29
μ_1			1.9410	2.09
μ_2			1.0	fixed
Cost-time trade-off	0.2456		0.2800	
Estm. Parameters	6		7	
Final LL	-433.41		-430.52	
Adjusted ρ^2	0.4210		0.4236	

Supply Chain Variables

Detailed specification

- 20 additional explanatory variables are all statistically significant
- There is no statistical difference in model fit between MNL and CNL
- Unobservable correlation now becomes observable

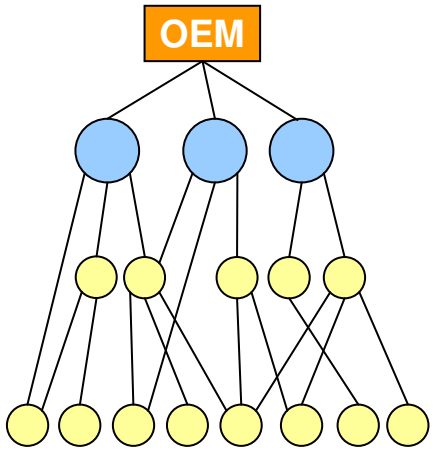
	Attributes	MNL		CNL	
		Value	t-test	Value	t-test
	For-hire road constant	1.2059	1.83	1.1758	1.61
	Rail constant	1.7140	2.00	1.6840	2.11
	Combined road-rail constant	-1.5979	-0.99	-1.5709	-0.98
Level-of-service attributes					
	Cost (%)	-0.0709	-11.74	-0.0694	-4.33
	Time (hour)	-0.0200	-3.32	-0.0197	-3.25
	Delay (%)	-0.0066	-0.98	-0.0066	-1.00
Shipper characteristics					
RH,RL,CB	Annual tonnage shipped	0.0018	2.93	0.0018	2.38
CB	Combined used in the last 12 months	4.3639	3.13	4.2911	2.89
RO	No. of own truck; $\geqslant$ 3.5 tons	0.0508	4.33	0.0497	3.14
RL, CB	Use of warehouse	1.2857	2.22	1.2643	1.98
RH,RL,CB	Contract type (long-term=2, equal=1, occasionally=0)	0.3199	2.64	0.3124	2.22
RO	Transport organised by shippers	0.6308	3.10	0.6139	2.26
CB	Transport organised by providers	-1.7199	-3.78	-1.6905	-3.29
RH	Access to domestic parking area	-0.5700	-1.94	-0.5567	-1.76
RH	Zone type of parking; specific to freight	-4.3809	-5.74	-4.2758	-3.32

	Attributes	MNL		CNL	
		Value	t-test	Value	t-test
Shipment & flow characteristics					
RO	Time of departure	-1.1818	-5.38	-1.1553	-3.30
CB	Time of departure	-2.0395	-2.17	-2.0138	-2.16
RO	Distance	-0.0022	-2.81	-0.0021	-2.19
RH	Fragile products	-1.4942	-3.68	-1.4653	-3.27
RL, CB	Fragile products	-3.6384	-2.70	-3.5893	-2.75
RO	Bulky products	-1.1214	-3.03	-1.0994	-2.68
RL, CB	Weight of shipment	0.0455	1.90	0.0449	1.88
RH	Shipment is a part of journey	-0.6565	-2.85	-0.6432	-2.52
CB	Shipment is a part of journey	4.0222	3.19	3.9522	2.82
RH	RFID or electronic labels	0.8830	3.07	0.8631	2.64
CB	RFID or electronic labels	2.3871	2.39	2.3449	2.31
	μ_1			1.0356	0.10
	μ_2			1.0	fixed
	Cost-time trade-off	0.2821		0.2839	
	Estimated Parameters	26		27	
	Final LL	-317.25		-317.25	
	Adjusted ρ^2	0.5478		0.5464	

Analysis and Results

- Supply chain variables
  - Unobserved correlation amongst different modes
  - Degree of closeness (e.g. type of contract)

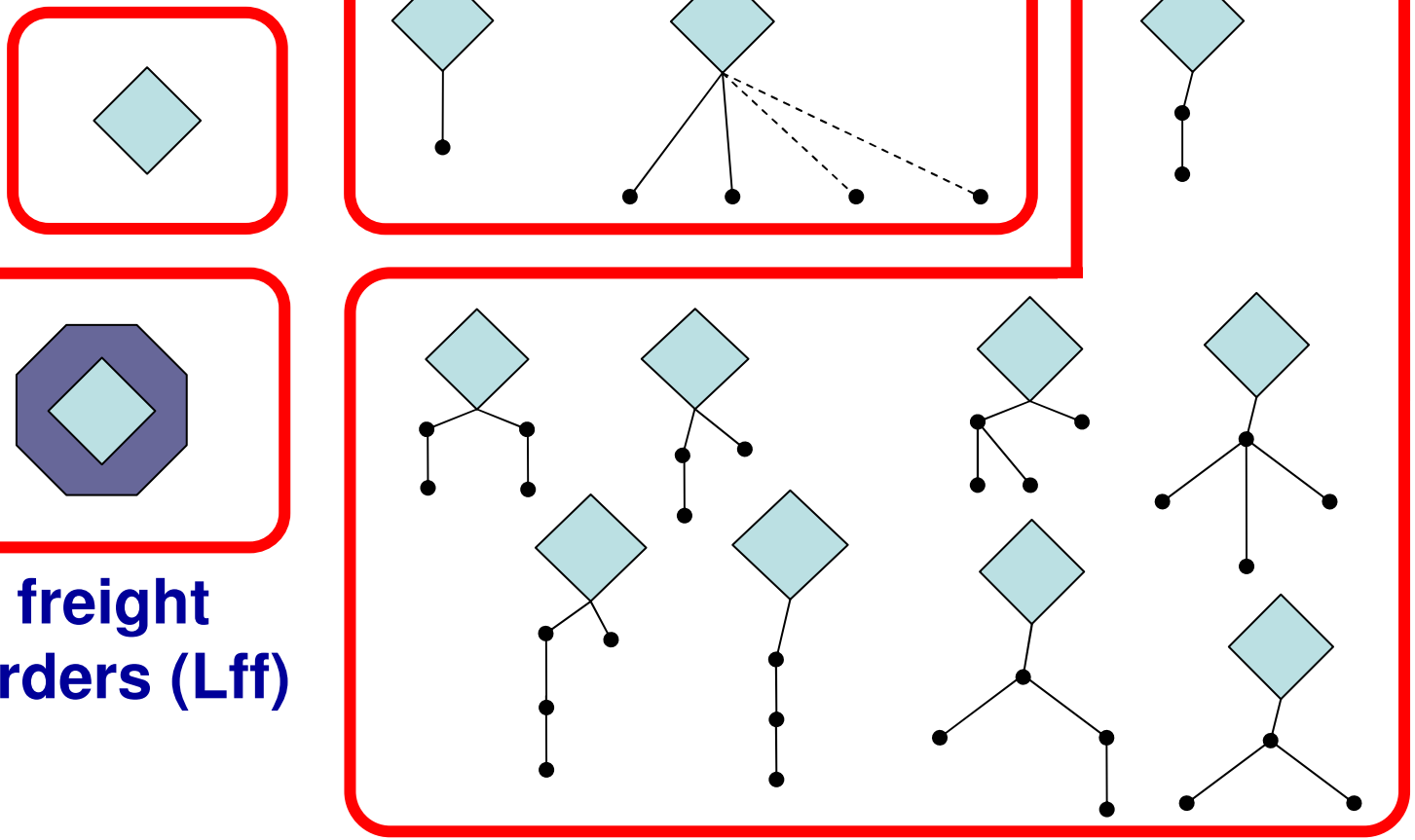
- **Supply chain structures**
  - Unobserved correlation along two choice dimensions: transport mode and supply chain



Supply Chain Structures

Shippers using Own account road (ShpRO)

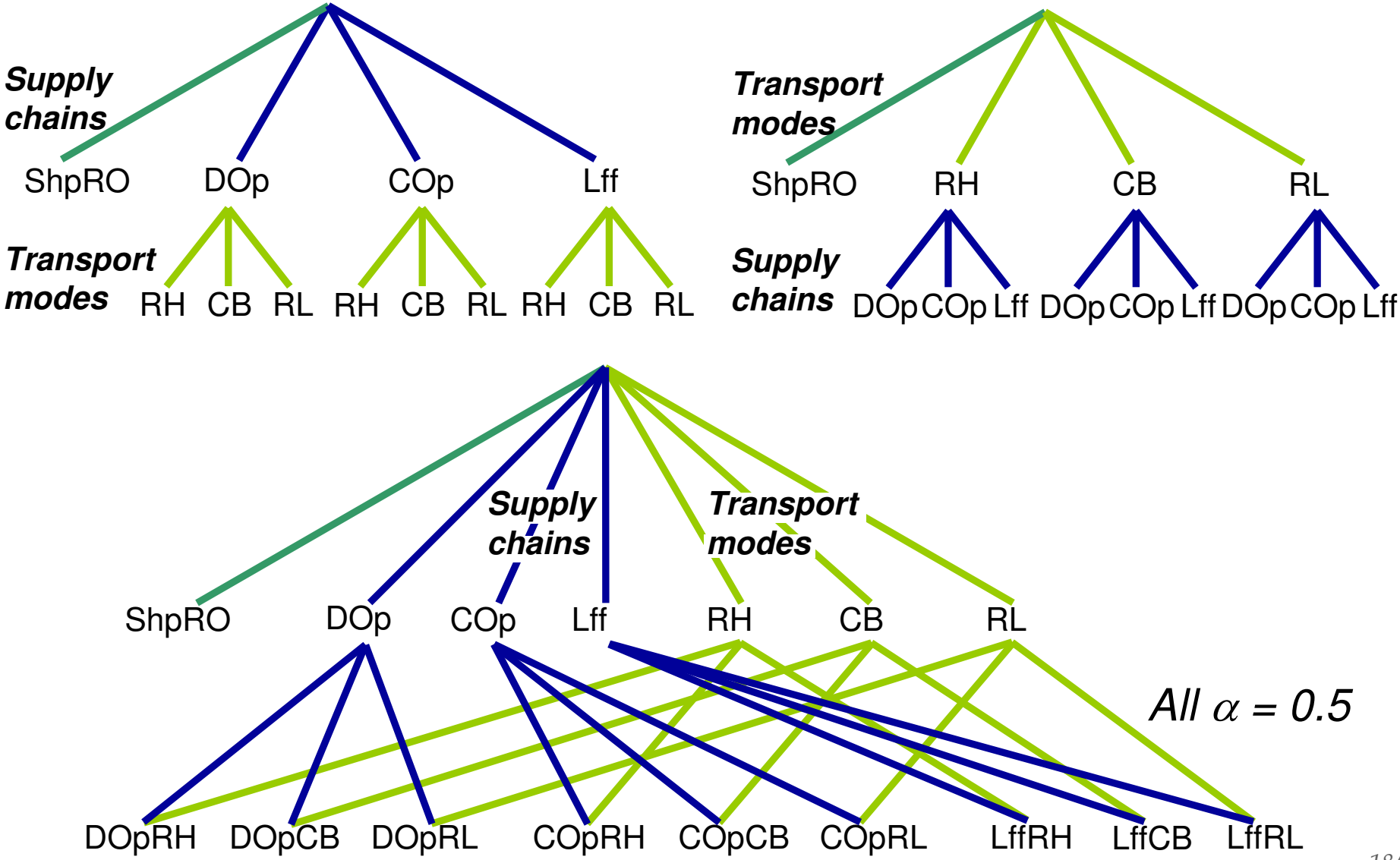
Directly contacted Operators (DOp)



Large freight forwarders (Lff)

Chaining Operators (COp)

Supply Chain Structures



Supply Chain Structures

- Both NL models do not statistically outperform the MNL model
- Correlations exist amongst alternatives within the nests of Directly Contacted Operators chain and Combined road-rail mode
- CNL provides the best model fit
- MNL overestimates the value of cost-time trade-off

Structural Parameters (μ)	MNL	CNL		CNL Re-estimated	
		Value	t-test	Value	t-test
ShpRO		1.0	fixed	1.0	fixed
DOp		5.301	1.99	11.382	2.65
COp		1.128	0.18	1.0	fixed
Lff		1.0	fixed	1.0	fixed
RH		1.014	4.26	1.0	fixed
CB		1.837	1.52	2.943	3.47
RL		1.095	0.03	1.0	fixed
Cost-time trade-off	0.2515	0.2271		0.2420	
Estimated Parameters	24	29		26	
Final LL	-704.10	-702.04		-700.56	
Adjusted ρ^2	0.5328	0.5309		0.5338	

Supply Chain Structures

Choice elasticities

- Shippers with complicated supply chains are more sensitive to time *than* shippers with simple chains

- For-hire road:
  more competitive to the other modes in the same chain *than* the same mode in the other chains

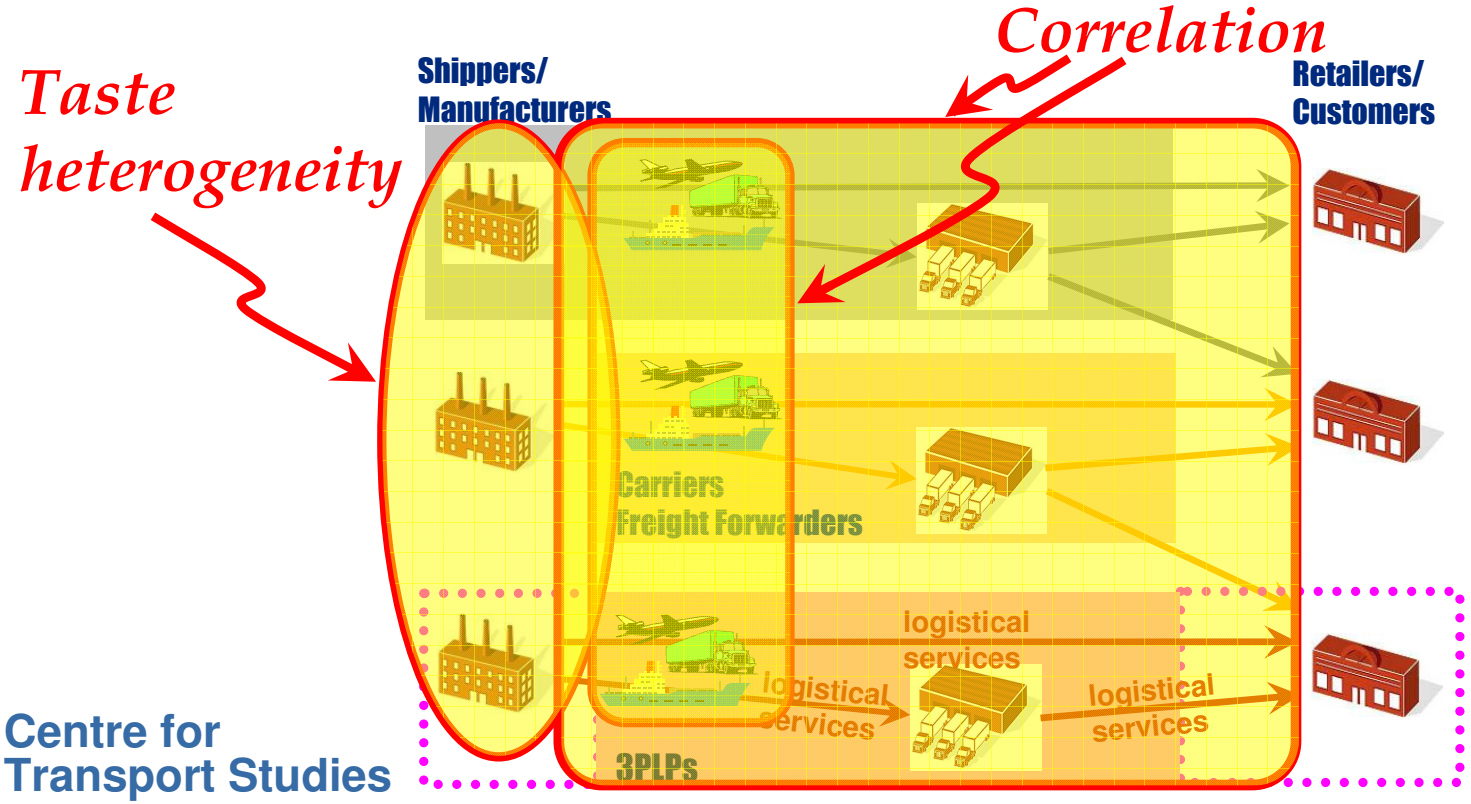
- Rail and Combined road-rail:
  more competitive to the same modes in the other chains *than* the other modes in the same chain

Conclusions (1)

- Apart from cost and time, logistical and supply chain attributes are also the major determinants of demand
- Unobserved correlation amongst mode and/or supply chain alternatives must be properly taken into account
- The study offers greater insight into shippers' choice behaviour with respect to modes and supply chains
- Failure to properly account for these observed and unobserved supply chain influences leads to
  - Degraded explanatory power of freight demand models
  - Increased risks of misinterpreted results and violated policy implications

Conclusions (2)

- Future work
  - Interdependent choice process amongst agents
  - Models accounting for inter-alternative correlation and inter-agent taste heterogeneity simultaneously



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