A discrete shipment size choice model with latent classes of shipments' attributes

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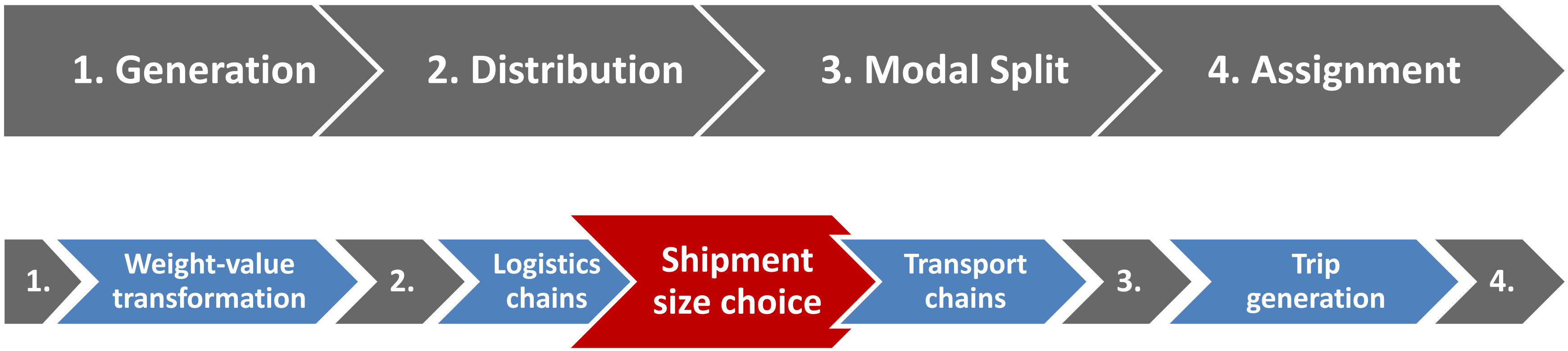
Agenda

- Introduction
- Discrete shipment size choice model
- Latent classes of shipment‘s attributes
- Data and estimation results
- Summary and prospects

Introduction

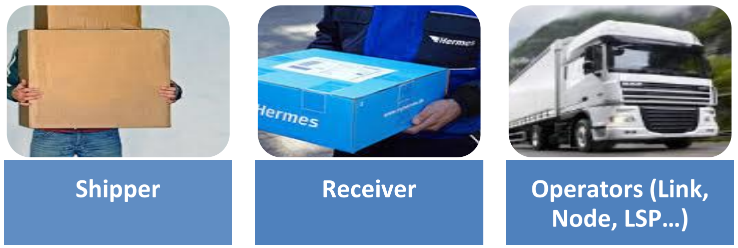


- Why shipment size choice modeling?
  - High relevance for subsequent decisions (mode choice, transport chains)
  - Proxy for logistical decisions
  - Displays reactions of various stakeholders on policy measures (behaviorally-sensitive)

→ Important aspect in the modeling of freight transport demand

Introduction - Challenges

- Huge variety of deciding subjects



- Enormous diversity of corresponding objects (transported commodities)

- (Disaggregate) data availability is strongly limited
- Simulation-related analysis is problematic (adequate level of abstraction)

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Introduction - Approach

- Two questions arise:
  1. How can the shipment size choice be modelled behaviorally-sensitive?
  2. How can the heterogeneity be addressed in a managable way?
- Approaches:
  1. Discrete shipment size choice model
     - Total logistics cost as rational core
     - Shipment sizes show up empirical dependency on given vehicle and bundle sizes
     - Operationalization in large-scale freight transport model systems
  2. Latent Classes of shipments attributes
     - Similar behavior (similar logistical characteristics)
     - Less data requirements

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Discrete shipment size choice model – Total logistics cost

- Total logistics cost (TLC) per year for decision maker n:

$$C_n(q_n) = \frac{Q_n}{q_n} F_n + Q_n c_n(q_n) + \frac{q_n}{2}(w_n + r v_n)$$

  - Q_n: Constant and continuous flow of goods regarding individual *n* per period (ton/year)
  - q_n: Shipment size per transport of individual n to satisfy Q_n (ton/shipment)
  - F_n: Fixed transport costs per shipment for individual n (cost/shipment).
  - $c_n(q_n)$: Variable transport costs for individual n dependent on shipment size q_n (€/ton)
  - w_n: Warehousing costs per unit of commodity per year for individual n (€/ton)
  - r: Interest rate valuing the bounded capital in form of inventory holding costs
  - v_n: Value density of the transported commodities (€/ton)

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Discrete shipment size choice model

- A discrete shipment size choice model requires shipment size categories $q_i, i = 1,2, \ldots, I$:

$$C_n(q_i) = \frac{F_n}{q_i} Q_n + c_n(q_i) Q_n + \frac{q_i}{2}(w_n + r v_n)$$

- Warehousing cost w_n mainly depend on handling and space consumption
  - w_n constant regarding each shipment size category
- Restriction to road transports - assumptions:
  - Fixed transport cost constant for all decision makers n
  - Variable transport cost only varying between shipment size categories
    - Approximation by piecewise linear function: transport cost t_{q_i} (per tkm) times the haulage distance d_n

$$C_n(q_i) = \frac{q_i w_{q_i}}{2} + \frac{F_{q_i}}{q_i} Q_n + t_{q_i} d_n Q_n + \frac{q_i r}{2} v_n$$

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Latent classes of shipment's attributes – Motivation

$$C_n(q_i) = \frac{q_i w_{q_i}}{2} + \frac{F_{q_i}}{q_i} Q_n + t_{q_i} d_n Q_n + \frac{q_i r}{2} v_n$$

- Cost components are affected by logistical attributes of the transport e.g.
  - Fix cost F_{q_i}: loading, unloading, processing of the commodities
  - Value of time v_n: importance of the good in the supply chain (JIT/JIS (time critical) production vs. lubricants and consumables)

- Segmentation approach: Latent Class Analysis
  - Exogenous segmentation
  - Externally visible segments
  - Segments of transports by similar response patterns on the basis of categorical items (logistical attributes)

Latent classes of shipment‘s attributes – Approaches of integration

- Piendl, Liedtke and Matteis (2015) :TLC approach with supplement and deductions to utility function

  (1) Food products (temperature-controlled)
  (2) Miscellaneous standard cargo
  (3) Special goods
  (4) Unpacked bulk goods

  - Reasonable order of coefficients' magnitudes: (1) < (2) < (3) < (4)

- Now: One discrete choice model per estimated segment $s = 1, \dots, S$, $\varepsilon_{q_i,n|s}$ distributed i.i.d. extreme value type I

$$-U_{q_i,n|s} = C_{n|s}(q_i) + \varepsilon_{q_i,n|s}$$

$$-U_{q_i,n|s} = \alpha_{q_i|s} + \beta_{q_i,1|s} \cdot Q_n + \beta_{q_i,2|s} \cdot Q_n d_n + \beta_{q_i,3|s} \cdot v_n + \varepsilon_{q_i,n|s}$$

Data and estimation results

- Survey conducted within the scope of the German federal infrastructure planning 2015 (BVWP)

- Computer Assisted Personal Interviews: 487 usable road transport observations due to calculation of variables, revealed preference (RP) data

- Detailed information about the transport were sampled:
  - Type, weight, value and characteristics of the transported commodity
  - Frequency of the transport
  - Position in the supply chain
  - Duration, costs and distance of the transport

- Classification of shipment sizes
  - Up to $3t$: Piece goods
  - $3t$ – $12t$: Partial truck loads
  - $> 12t$: (multiple) Full truck loads

Data and estimation results – Latent Class Analysis

- Four latent classes show best segmentation result

No. classes	Log-Likelihood	BIC
2	-2608.16	5371.02
3	-2541.76	5318.68
4	-2496.73	5309.06
5	-2470.68	5337.41
6	-2452.43	5381.36

- Characterization of classes:
  (1) Miscellaneous Goods (time-sensitive)
  (2) Special Goods
  (3) Food products (temperature-controlled)
  (4) Bulk Goods (time-insensitive)

Data and estimation results – Latent Class Analysis

	Class 1	Class 2	Class 3	Class 4
γ_s	0.3330	0.2060	0.0918	0.3692
		Conditional probability of answering "Yes"		
Fragile	0.0862	**0.5284**	0.2014	**0.0000**
Valuable	0.2619	**0.8194**	0.2320	0.2222
Bulky	0.3494	**0.4746**	**0.0000**	0.2543
Temperature	0.0549	0.0000	**0.7284**	0.0364
Food	0.0000	0.0000	**1.0000**	0.0740
Dangerous	**0.1947**	0.0187	0.0000	0.1588
Bulk Cargo	0.0173	0.0000	0.0458	**0.1677**
Liquid	**0.0000**	0.0000	0.0549	0.0142
Standard	**0.6500**	0.2512	0.6094	0.3068
Custom	0.1536	**0.4032**	**0.0446**	**0.0925**
Accumulation	**0.6669**	0.3674	0.5594	**0.0000**
Processing	**0.7278**	0.2551	0.4597	**0.1214**
Observations: 487				
Parameter estimated:51				

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Data and estimation results – Logit-Model

	Alternative	Miscellaneous Goods (time-sensitive)	Special Goods	Food products (temperature-controlled)	Bulk Goods (time-insensitive)
Constant	$q_2: 3t - 12t$	-5.6010.	-2.2337	2.8028	-4.2494
		(3.2884)	(4.2841)	(8.7964)	(3.9363)
	$q_3: > 12t$	-13.0818 **	-2.7417	0.1431	-9.2072 *
		(4.5164)	(5.3893)	(12.5992)	(4.6503)
Q_n	$q_2: 3t - 12t$	0.0020 .	0.0030	0.0031	0.0017
		(0.0011)	(0.0020)	(0.0030)	(0.0011)
	$q_3: > 12t$	0.0025 *	0.0036 .	0.0038	0.0019 .
		(0.0011)	(0.0021)	(0.0031)	(0.0011)
$\ln(d_n \cdot Q_n)$	$q_2: 3t - 12t$	0.6224 *	0.3207	0.4620	0.4449
		(0.2915)	(0.3961)	(0.8456)	(0.3535)
	$q_3: > 12t$	1.3248 ***	0.6415	1.1608	1.3862 **
		(0.3927)	(0.4842)	(1.2355)	(0.4310)
$\ln v_n$	$q_2: 3t - 12t$	-0.2261	-0.2120	-1.2991 .	-0.1407
		(0.2168)	(0.2597)	(0.7410)	(0.1813)
	$q_3: > 12t$	-0.5247*	-0.7237 *	-2.3739 *	-1.0163 **
		(0.2565)	(0.3227)	(1.1007)	(0.2831)
Number of observations:		162	92	42	191
Log-Likelihood:		-111.2	-67.1	-24.1	-101.6
McFadden R^2 (ρ^2):		0.3557	0.3228	0.4784	0.4400
Adj. McFadden $\overline{R}^2$ ($\overline{\rho}^2$):		0.3093	0.2421	0.3050	0.3959
Likelihood ratio test:		$\chi^2 = 122.74$	$\chi^2 = 64.00$	$\chi^2 = 44.15$	$\chi^2 = 159.6$

Significance levels: . p<0.1; * p<0.05; ** p<0.01; *** p<0.001

Summary and prospects

- Discrete shipment size choice models for interregional road transports have been developed
- Exogeneously derived latent segments of shipments‘ attributes account for omnipresent heterogeneity exceeding TLC variables
- Estimated models have reasonable signs and orders of the coefficients’ magnitude
- Problematic: low amount of observations in some of the estimated segments
- Incorporation of latent segments into a freight transport model framework needs to be investigated further
  - Sample biased
  - Adequate statistical mapping technique (NST 2007 to estimated segments

Thank you for your attention!