How to drive: New Insights in the Future of the German Automobile Market

Dr. Britta Niehof and Dr. Christian Winkler
Institute of Transport Research
German Aerospace Center

I. Introduction

Introduction

- *„**Millionengrab Pkw-Maut: Wenn die EU Nein sagt, bleibt Deutschland auf hohen Kosten sitzen**“ (Berliner Morgenpost, 4.6.2015)*
- *„**Zulassungszahlen für Elektro-Autos zeigen nach unten**“ (FAZ, 26.5.2015)*
- *„**Wie Abwrackprämie Bundesregierung will Elektroautos mit Milliarden fördern**“ (T-online, 02.6.2015)*
- *„**Autobestand erreicht 2022 seinen Höhepunkt**“ (Süddeutsche Zeitung, 30.9.2014)*

Facts

- Particulate matter & CO2 emissions
- 1 Million battery electric vehicles (BEVs) in 2020
- 95g/km of CO2 in 2021

- 7% of world market share
- 3% of German GDP
- 55% of export surpluses

II. Ideas

Data

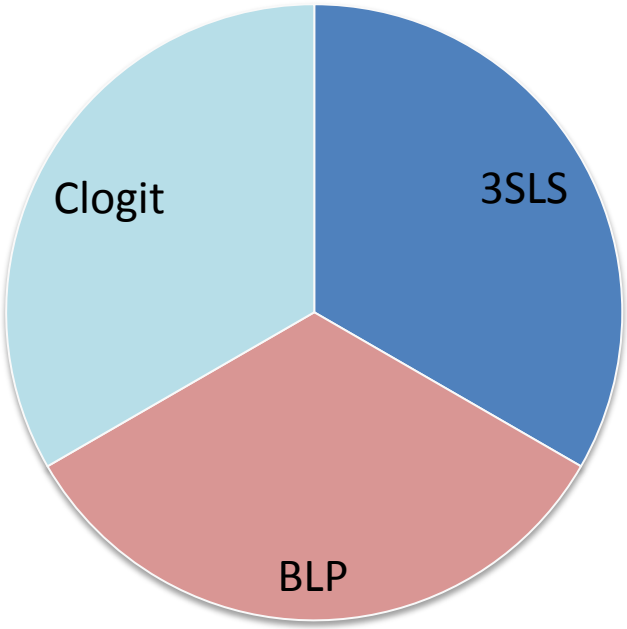
- 890 observations for 6 years (2003-2008)
  - Supply Side
    - Market Shares for 30 different car brands and types (KBA data)
    - Information on the respective vehicles, emissions, costs, prices, power (taken from ADAC data base)
  - Demand Side
    - socio-economic information for each type and brand (MID data)

Some descriptives

	Firms			households					firms			households			
brand	price	co2	age	income	status	m/f	full	brand	price	co2	age	income	status	m/f	full
Alfa Romeo	19221	184	38,00	4000,00	hoch	1,00	0,33	Seat	18285	156	34,00	3181,25	mittel	1,24	0,57
Audi	42730	188	44,00	3939,16	hoch	4,00	0,72	Skoda	16532	149	45,00	3123,71	mittel	1,96	0,62
BMW	49847	185	45,00	4105,70	hoch	2,94	0,64	Mazda	22248	179	41,00	3019,12	mittel	1,31	0,63
Chrysler	23864	221	43,00	4233,33	hoch	0,75	0,57	Mercedes Benz	62574	212	52,00	3852,99	hoch	2,01	0,53
Citroen	22611	164	44,00	3496,49	mittel	2,06	0,58	Mitsubishi	23958	191	44,00	3375,00	mittel	0,92	0,28
Daewoo	14866	183	47,00	3140,00	mittel	0,29	0,44	Nissan	27343	193	45,00	2920,37	mittel	1,27	0,50
Daihatsu	11682	140	50,00	3663,64	mittel	1,17	0,46	Porsche	73339	247	44,00	5412,50	sehr hoch	6,00	1,00
Fiat	17001	146	42,00	3339,74	mittel	1,36	0,47	Rover	17750	172	58,00	2950,00	mittel	2,00	0,33
Ford	18502	143	43,00	3293,36	mittel	1,05	0,53	Suzuki	14856	149	48,00	3235,14	mittel	1,00	0,48
Hyundai	20650	174	46,00	3176,47	mittel	1,00	0,54	Toyota	20634	154	47,00	3197,62	mittel	1,59	0,47
Jaguar	57924	217	39,00	3100,00	hoch	2,00	1,00	VW	29885	184	42,00	3511,38	mittel	1,34	0,53
Lada	10254	218	30,00	2900,00	mittel	2,00	1,00	Volvo	30648	196	46,00	4025,00	hoch	2,88	0,77
Lancia	21407	166	44,00	3740,00	hoch	1,00	0,83	Honda	22698	166	51,00	3379,31	mittel	1,18	0,58
Opel	21965	162	42,00	3285,62	mittel	1,37	0,52	KIA	18414	166	48,00	3400,00	mittel	1,00	0,67
Peugeot	22170	164	40,00	3684,54	mittel	0,76	0,50	Ferrari	144310	310	49,00	2900,00	mittel	0,00	0,00
Renault	20491	174	44,00	2979,11	mittel	0,83	0,38	SMART	11755	109	49,00	4404,76	hoch	0,67	0,40
Saab	20774	178	56,00	4880,00	hoch	2,00	0,33								

Empirical insights

- Many roads lead to results



Empirical insights (I)

- Ad-hoc idea:
  - Compute a mesoscopic model of demand and supply
    - supply is characterized by the market share of each brand
    - demand is characterized by the market share of each brand within a consumer group (grouped by income and household size)
  - Estimate the model using **3-stage least square** (IV) estimation

Empirical insights (I)

	Demand		Supply	
	param	std.err.	param	std.err.
price	-0,01	0,00 *	0,04	0,00 *
age	0,08	0,02 *		
male/female	-0,89	0,29 *		
hp	-0,17	0,02 *	-10,75	1,15 *
low income	-0.24	1.27		
medium income	4,33	1,32 *		
high income	7,85	1,28 *		
very high income	2,19	1,39		
co2	-0,04	0,02 *	-8,37	0,82 *
cost	0,02	0,00 *	1,51	0,18 *
constant	6,95	2,67 *	1,85	0,11 *
Demand	12%			
Supply	17%			

- The higher the price, the fewer the demand
- The demand for cars is smaller the higher the share of women
- Bigger incomes are more likely to buy a car
- The dirtier the car, the smaller the demand
- The bigger the horse power, the smaller the market share
- The dirtier the car, the smaller the market share
- …

Empirical insights (II)

- **BLP** (Steven T. Berry, James Levinsohn, and Ariel Pakes)

- Indirect Utility of consumer for product *j* is given by

$$u_{ij} = X_j \beta_i + \alpha \ln(y_i - p_j) + \xi_j + \varepsilon_{ij}$$

- Where
  - X_j is a vector of product characteristics for product *j*
  - β_i is a vector of coefficients which differs across consumers
  - α is a price coefficient
  - p_j is the price for product
  - ξ_j consumers' valuation of an unobserved product characteristics
  - ε_{ij} is an i.i.d. utility shock across consumers and choices

Empirical insights (II)

- Derive market-level (aggregate) share expression from individual model of discrete-choice
- The probability that individual *i* chooses *j* is given by

$$s_{ijt} = \frac{\exp\left(X_j\beta_i + \alpha\ln(y_i - p_j) + \xi_j\right)}{\sum_k \exp\left(X_k\beta_k + \alpha\ln(y_k - p_k) + \xi_k\right)} = \frac{1}{M}\left[Ms_{ijt}\right]$$

- Model differs from standard conditional logit in two ways:
  - First, unobserved demand shock ξ
    - consumers are willing to pay more for products for which ξ_j is high
    - firms know product quality, which means ξ_j is correlated with price (and also potentially with characteristics X_j)
    - unobserved product characteristic is source of the endogeneity problem

Empirical insights (II)

	param	std.err			param	std.err
HP	6,68	1,43 *	Opel		0,99	0,61
Alfa Romeo	-2,24	0,74 *	Peugeot		-0,74	0,60 *
Audi	0,80	0,60	Renault		0,02	0,63
BMW	1,59	0,57 *	Saab		-5,43	1,11
Chrysler	-3,50	0,82 *	Seat		0,73	0,68
Citroen	-0,46	0,61	Skoda		0,47	0,67
Daihatsu	-1,72	0,71 *	Suzuki		-0,78	0,66
Fiat	-0,54	0,63	Toyota		-0,51	0,64 *
Ford	1,02	0,62	Volvo		0,24	0,63
Honda	-1,13	0,70	VW		1,81	0,59 *
Hyundai	-1,43	0,63 *	used car		-0,08	0,88 *
Jaguar	-8,12	1,20 *		A	-0,90	0,70
Kia	-1,88	0,64 *		C	0,08	0,60
Lancia	-2,53	0,83 *		D	-0,09	0,56
Mazda	-0,17	0,64		E	-0,27	0,56
Mercedes	3,44	0,64		F	-0,62	0,57
Mitsubishi	-1,16	0,61		G	-1,76	0,72 *
Nissan	-1,05	0,67	price		-6,62	0,87 *

- Brands matter
- There is a significant difference between new and used cars
- The higher the price, the smaller the market share
- The dirtier the car (category G), the smaller the market share
- …

Empirical insights (III)

- **Clogit**

  Indirect Utility of consumer for product j is given by

$$u_{ij} = \alpha X_j + \varepsilon_{ij}$$

- The probability that a subject will choose an alternative is

$$\pi_{ij} = \Pr\{Y_i = j\} = \Pr\left\{\max\left(U_{i1},\ldots,U_{in}\right) = U_{ij}\right\}$$

- Where
  - X_j is a vector of product characteristics for each product
  - α is a coefficient
  - ε_{ij} is an i.i.d. utility shock across consumers and choices

Empirical insights (III)

	param	std	
income	0,00		
availability	-0,06	0,03	*
tco	-0,01	0,00	*
#cars	0,00		
vmt			
15	3,24	0,89	*
20	6,42	1,76	*
25	7,30	2,52	*
30	10,96	3,44	*
40	15,90	5,27	*
vmt~job	0,05	0,02	*
long distances	0,13	0,03	*
fuel~vmt	-0,14	0,02	*
dist working place	0,00	0,01	*
large	-0,01	0,95	
male	0,35	1,35	
2nd car	1,80	0,32	*
price	-0,00	0,00	*
value~income	0,00	0,00	
tco~income	0,00	0,00	

- People dislike high car prices
- People prefer driving cars with low tco
- Vmts determine the car choice
- People prefer buying two different cars
- Being employed determines the car choice
- …

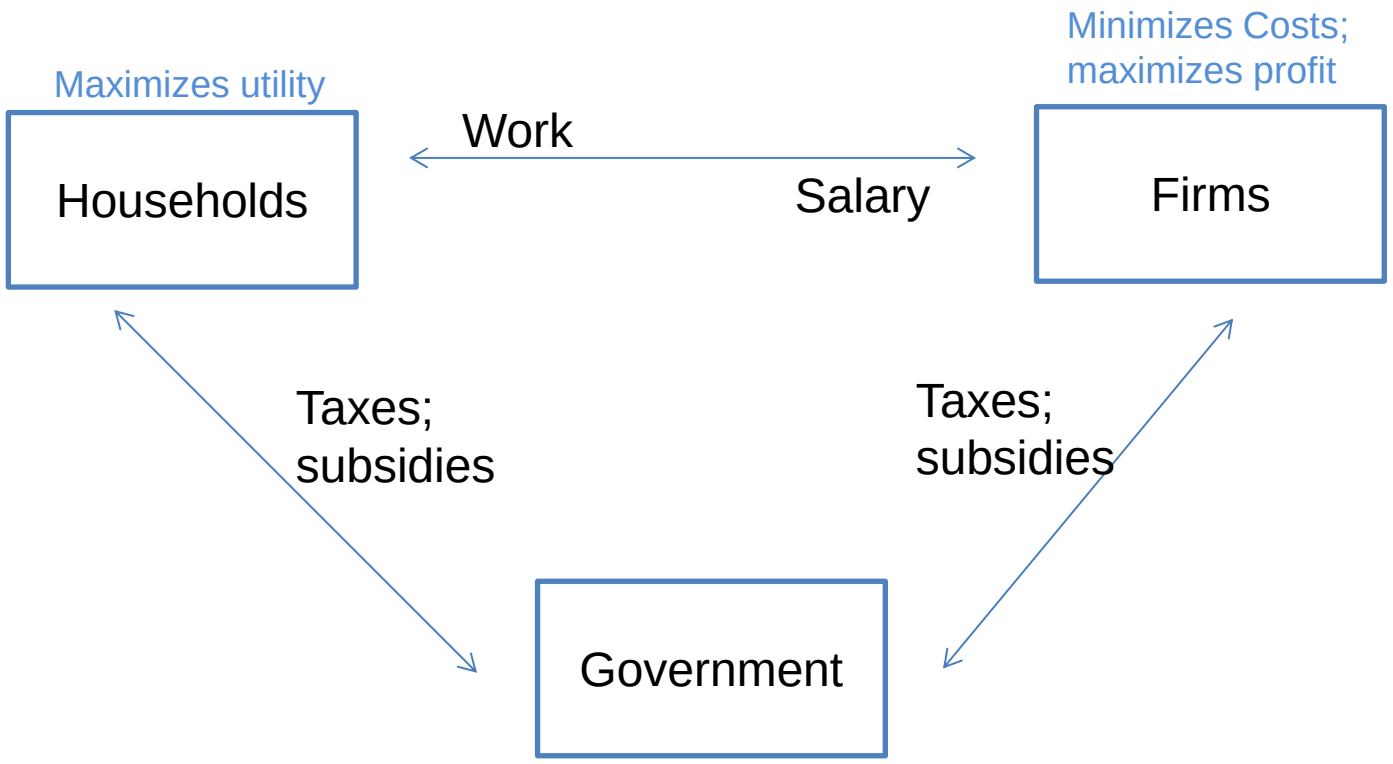
III. Open questions remain…

Open questions

- How can we better differentiate between new and used cars?
- How are the dynamics between supply and demand?
- How can we analyze policy measures properly?
- How do we account for company cars?
- …

IV. Theoretical model

Households


Maximizes utility
Households
Work
Salary
Minimizes Costs;
maximizes profit
Firms
Taxes;
subsidies
Taxes;
subsidies
Government

Households

- Combine macroeconomic modelling with transportation economics
  - Steven T. Berry, James Levinsohn, and Ariel Pakes, 1995. “Automobile Prices in Market Equilibrium,” Econometrica, vol. 63(4), pp. 841-890
  - Smets, Frank, and Rafael Wouters. 2007. "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." American Economic Review, 97(3): 586-606.
  - Oh, Hyunseung 2013. “The role of durables replacement and second-hand markets in a business-cycle model” Columbia University Working Paper
  - …

Households

- A consumer owns none, one or two durable goods.
- She gains utility from driving a car, the amount of utility depends on the car.
- She has perfect information.
- She can always opt for the outside option, the selling option respectively.
- At the beginning of each period, each consumer might have an endowment from owning a vehicle.
- At the beginning of each period she decides to maintain her current status or purchase a (new) car. She can furthermore sell her old car or scrap it.
- Each car is described by observed and unobserved characteristics. Furthermore, it is described by the observable individual price and unobservable transaction costs.

Households

- The utility of a consumer is

$$u_{it}^{kj} = \frac{1}{1-a_x} x_{mt}^{1-a_x}(i) + \frac{1}{1-a_\xi} \xi_{mt}^{1-a_\xi}(i) + \frac{1}{1-a_c} c_{mt}^{1-a_c}(i) + \frac{1}{1-a_h} h_{mt}^{1-a_h}(i)$$

$$x_{mt} = x_{mt}^{c}(i) + (1-\delta_x) x_{mt-1}(i)$$

$$\xi_{mt} = \xi_{mt}^{c}(i) + (1-\delta_\xi) \xi_{mt-1}(i)$$

- $m \in \{1,2\}$ is the index for an owned or a new car.
- α_x and α_ξ: individual-specific preferences for car characteristics.
- α_c and α_h : individual-specific preferences for general consumption and labor.
- c_t is the composite commodity, h_t are hours worked.
- The same product in subsequent years differs by its age and by its unobservable characteristics.

Households

- A household maximizes her utility subject to her inter-temporal budget constraint

$$\max\left(\sum_{t=0}^{\infty}\sum_{k=0}^{K}\beta_t u_{ik}(x_{mt},\xi_{mt},c_t,h_t,\varepsilon_t)\right)$$

$$s.t.\left(a\left(z_t(i)\right)-r_t^k z_t(i)\right)k_{t-1}(i)+b_t-r_t b_{t-1}+p_t^c c_t+p_{jt}$$
$$+p_{it}-p_{mt}(1-\delta_{mt-1)}-p_{nt}(1-\delta_{nt-1})+tax_t=w_{it}h_{it}$$

- Where $y_{it}=w_{it}h_{it}$ is the period-income, b_t are bonds, p_{it} are prices for cars.

Firms

- Market Structure
  - Second-hand retailers observe the purchasing price P_{mt} of the bundled good and decide whether to enter or not, based on their expectations of the unbundled prices $p_{dt}(i)$
  - Each new durable producing firm sets the price of its variety $p_{dt}(i)$, taking into account both the direct effect on the total demand function, and the indirect effect on the response from the price-taking second-hand retailers who entered the market.
  - The entrant retailers observe the price that the leader sets and choose the supply of the unbundled goods, given their pre-purchased bundled good when they entered the market.

Firms

- New goods are produced under monopolistic competition and distributed fully competitive.
- Retailer maximize their profits subject to their CES production function

$$\max\left(P_t Y_t - \int_0^1 Y_t^j \right) \qquad s.t. \qquad Y_t = \left(\int_0^1 \left(Y_t^j \right)^{\frac{1}{\mu_t}} dj \right)^{\mu_t}$$

- The retailers' demand for cars is then $y_t\left(\frac{p_{dt}}{p_{dt}(j)} \right)$

Firms

- New goods are produced under monopolistic competition and distributed fully competitive.
- Marginal costs mc_{td} are derived by a firms cost minimization subject to its production technology

$$\min\left(w_t h_t + r_t k_t\right) \qquad s.t. \qquad y_t(j) = A k_t(j)^{\alpha} h_t(j)^{1-\alpha} - \Psi$$

- Firms then maximize their profits subject to the retailers demand

$$\max \pi_{nt}(j) = p_{tg}(j) y_t(j) - mc_{tg}(j) y_t(j) - mc_{tg}(j)\Psi$$

- Firms are not able to control the second-hand market.

Firms

- Second-hand firms purchase used goods from households (at price p_{ut}) and refurbish them to sell them to second-hand retailer (at price p_{mt}).
- A second-hand firm faces costs p_{rt} for refurbishing a good
- A second-hand firm maximizes his profits $\pi_{ut} = p_{mt} m_t - p_{ut} m_t - p_{rt} m_t$
- The equilibrium purchasing price is given by $p_{ut} = p_{mt} - p_{rt}$
- The retailer then unbundles $m_t = \sum_{t=0}^{\infty} m_t(j)$

Closing the model…

- The model closes by households wage optimization and by including monetary policy and government spending
- Further policy measures can be included here, i.e. subsidies or taxes

Outlook

- Conduct an estimation which captures the full model, i.e. using Bayesian techniques