The extended Multiple Discrete-Continuous Extreme Value (MDCEV) Model (multiple car case)

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1. Scope and motivation

Examining the effects of
   i.) a fuel tax
   ii.) a tax on car ownership
   on
   a.) aggregate annual mileage of cars
   b.) car ownership and the proportion of carless households
   c.) car choice with respect to car type and thus to fuel efficiency (new!)
2. Method

Discrete Choice Model

\[
\max_i U_i = V_i + \varepsilon_i
\]

- \(U_i\): Utility of product type \(i\)
- \(V_i\): Deterministic component
  \[V_i = V_i(x_i, s)\]
  - \(x_i\): Product properties
  - \(s\): Sociodemographic attributes of the household
- \(\varepsilon_i\): Stochastic component. (Represents unobserved product properties, etc.)

“Choose the product type \(i\) that provides the highest utility!”
Discrete-continuous Choice Model (MDCEV)

"Which car(s) are owned and how many km’s they are driven?"

\[
\max_{s_i} u_i = u(x, \epsilon); \quad x, \epsilon \in S_i, \quad S_i \subset \mathbb{R}^n, \text{eg.: } S_i = (x_1, 0, x_3, x_4, 0, x_6)
\]

s.t. economic constraints

\[
x = x_i(y, p, \epsilon); \quad p, \epsilon \in S_i
\]

Prefernces

Optimal consumption (Mashallian Demand Function)

\[
u_i = u(x_i, \epsilon)
\]

Utility

\[
u_i = u(x_i, \epsilon) \text{ microeconomic utility function,}
\]

\[
\epsilon_i : \text{Stochastic component. (Represents unobserved consumer preferences, etc.)}
\]

"Choose the combination of car(s) $S_i$ that yields the highest utility!"
Remarks:

- **Why a microeconomic utility function?**
  - *I must relate the utility level to a driving distance*
  - *I want to make use of the properties of the microeconomic theory, here:*
    - **“Normal good”:**
      - Demand increases with income ...
      - ... and decreases with its own price
    - **Imposes restrictions on the demand function**
      - Demand functions are economically consistent
- The utility function has a stochastic component, thus the Marshallian demand function is stochastic too
- This modelling framework clearly separates the effect of changes of the preferences and changes in the economic environment (income and prices)
3. Basic idea behind the model

![Diagram of household decision with four pathways: No car, Car type 1, Car type 2, Both cars. Each pathway includes income, driving costs, and optimal mileage conditions.]

**Choice:** \( \arg \max_{i=1,4} \left( u_{(1)}, u_{(2)}, u_{(3)}, u_{(4)} \right) \)
4. The model (multiple car case)

\[
\max_{x_1, x_2, \ldots, x_{n+1}} u(x_1, x_2, \ldots, x_{n+1}) = (x_1 + a_1)^d + \sum_{i=1}^n \exp(m_{i+1} + \beta \cdot \zeta_{i+1}) \cdot (x_{i+1} + a_{i+1})^d
\]

Subject to: \[y = \sum_{i=1}^n I(x_{i+1} > 0) \cdot k_{i+1} + p_1 \cdot x_1 + \sum_{i=1}^n p_{i+1} \cdot x_{i+1},\]

for each possible combination of car choice, e.g. \((x_1, x_2, 0, x_4, 0, \ldots, 0)\).

\(k_{i+1}\): Fixed costs of car type \(i\)
\(x_{i+1}\): Car-km with car type \(i\), \(i = 1..n\)
\(x_i\): Composite good: All other goods (housing, holidays, consumption goods, …)
\(p_{i+1}\): Marginal costs of a car-km of car type \(i\) (note: \(p_1 = 1\))
\(m_{i+1} + \beta \cdot \zeta_{i+1}\): Relative preference for driving car type \(i\)
\(\beta \cdot \zeta_{i+1}\): Stochastic component of the relative preference for driving a certain car
\(\zeta_i\): Standard-Gumbel distributed

Example: \(m_i = \gamma_{i,0} + \gamma_{i,1} \cdot rural\), where \(rural = 1\) if the household lives in a rural area
5. Simulation results (two car case)

Figure 1: Preference for certain car types and choice of car combinations
Figure 2: Simulated density function of a household with an annual income of CHF 84,000
Figure 3: Simulated density function when the fuel price increases by 50%
Figure 4: Change in annual mileage when the fuel price increases
Figure 5: Change in annual mileage when the fuel price increases
6. Existing model and key results

- The existing model – the extended MDCEV model (one car case) – captures only one car type

- The key results are:
  i.) the main effect of a fuel tax on the aggregate annual mileage is that “heavy users” will decrease the distance driven and not that households will sell the car
  ii.) the effect of a fuel tax on the aggregate annual mileage is much greater than the effect of a tax on car ownership – per unit of tax revenue
7. Discussion

- Estimation routine?
- Results driven by the specification of the model structure?
- Substitutionability between car types mapped by the model?