Modeling residential location choice and real estate prices with a bid-auction approach

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Outline

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2. Bid approach for location choice
3. Proposed method
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5. Discussion
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Motivation

- Evolution of land use (location choice) models:
  - Aggregated → Disaggregated
  - Equilibrium → Dynamic microsimulation

- Market clearing / location distribution:
  - Bid-auction
  - Choice

- Bid approach: consistent with economic theory. Usually implemented in equilibrium models (e.g. MUSSA)

- Choice approach: easier to implement in a microsimulation context (e.g. UrbanSim). Requires hedonic rents/prices
Motivation

- Bid-auction approach applied to microsimulation
  - Price formation problem
    - consistency with observed prices
    - Reaction to market conditions
  - Dynamics (pseudo-equilibrium)
  - Active bidders in the auction (choice set)
Bid approach for location choice

Assumptions:
- Real estate goods (locations) are traded in auctions
- Agents bid their willingness to pay for each location ($B_{hi}$)
- For each location the best bidder is selected
- The amount/value of the best bid determines the rent/price
Bid approach for location choice

- Probability of agent \( h \) being the best bidder for location \( i \):

  \[
P_{h/i} = \frac{\exp(\mu B_{hi})}{\sum_{g \in H} \exp(\mu B_{gi})}
  \]

- Expected maximum bid (rent):

  \[
r_i = \frac{1}{\mu} \ln \left( \sum_{g \in H} \exp(\mu B_{gi}) \right)
  \]
Bid approach for location choice

- Problems:
  - Requires equilibrium between supply and demand (or at least demand > supply)
  - In the case of supply surplus it not clear which locations are not selected
  - Logsum ($r_i$) doesn’t necessarily reproduce observed prices or rents
Proposed framework

- Bid based location choice model
- Assumptions:
  - Goods (locations) traded in auctions, period-wise
  - Agents bid their willingness to pay for each location
  - Agents adjust the level of their bids as a reaction to market conditions (represented by observed prices)
  - Agents are myopic regarding the outcome of future and present auctions
Proposed framework

- Bid function:

\[ B_{hi}^t = b_h^t + b_{hi}^t \]

Bid adjustment (utility level)  
Willingness to pay for attributes

\[ b_{hi}^t = f(z_{i-1}^t, x_h^t, \beta) \]  
estimated via max log-likelihood, assuming \( b_h^t = 0 \)
Proposed framework

- Bid adjustment:

Bidding households attempt to ensure winning, on average, at least one auction:

\[
\sum_i P_{h/i}^t = \sum_i \frac{\exp(b_h^t + b_{hi}^t)}{\sum_{g \in H} \exp(B_{gi}^t)} = 1 \quad \forall h
\]

But… households do not observe bids of other households in the same period. They can only observe transaction prices in previous periods

\* \(\mu = 1\)

\(H : \text{full choiceset}\)
Proposed framework

- Bid adjustment:

\[
\sum_{i \in S} P_{h/i}^t = \sum_{i \in S} \frac{\exp(b_{h}^t + b_{hi}^t)}{\sum_{g \in H} \exp(B_{gi}^{t-1})} = 1
\]

\[
\sum_{g \in H} \exp(B_{gi}^{t-1}) = \exp(r_i^{t-1})
\]

\(S\): full choice set of dwellings/locations
Proposed framework

- In each period:
  \[ b_h^t = -\ln \left( \sum_{i \in S} \exp(b_{hi}^t - r_{i}^{t-1}) \right) \]

- In the base year (calibration year):
  \[ b_h^0 = -\ln \left( \sum_{i \in S} \exp(b_{hi}^0 - r_{i}^{*}) \right) \]

Observed prices at the base year
Price dynamics

- Simulation of a supply surplus scenario with synthetic data

[Graph showing price dynamics with periods from 0 to 20 and Rent values from 0.5 to 3.0, with lines indicating low and high scenarios and a noted supply shock (increase).]
Brussels case study

- Data collected for the SustainCity project:
  - Census 2000 (aggregated data by zone)
  - Household survey 2000 (disaggregated data, ~1000 obs)
  - 1985-2008 average transaction prices by commune and dwelling type

- 1267997 households, 1274701 dwellings
- 157 communes
- 4975 zones
- 4 types of dwelling
  - Detached houses
  - Semi-detached houses
  - Attached houses
Brussels case study

- **Bid function specification:**

  $$b_{hv} = \beta_{surf} \cdot surf_{vi} \cdot \ln(N_h) + \beta_{sup} \cdot Q_i^{sup} \cdot N_h^{sup} + \beta_{house} \cdot \lambda_{vi}^{house} \cdot N_h +$$

  $$\beta_{trans} \cdot Y_i^{trans} \cdot \gamma_{h,cars=0} + \beta_{trans2} \cdot Y_i^{trans} \cdot \gamma_{h,cars>1} + \beta_{comm} \cdot Y_i^{comm} \cdot \ln(N_h) +$$

  $$\beta_{off} \cdot Y_i^{off} \cdot W_h + \beta_{green} \cdot Y_i^{green} \cdot W_h + \ln \phi_h$$

- $surf_{vi}$: average surface of a residential unit in buildings type $v$ in zone $i$ (calculated from the census).

- $N_h$: number of individuals in a household.

- $W_h$: number of active individuals (workers) in a household

- $N_h^{sup}$: number of persons in the household who achieved a university degree as their maximum education level.

- $Q_i^{sup}$: percentage of the population in zone $i$ with a superior level education-degree.

- $Y_i^{trans}$ measurement of the quality of public transport (accessibility)

- $Y_i^{comm}, Y_i^{off}, Y_i^{green}$: measurement of the presence of commerce, offices and public green areas

- $\phi_{vi}$ correction factor for the household-sampling protocol.
Brussels case study

- Estimation results with PythonBiogeme

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<th>Value</th>
<th>Std err</th>
<th>t-test</th>
<th>p-value</th>
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- Likelihood ratio test against null model 219.4
Brussels case study

- Number of people by commune
Brussels case study

- Number of people with university degree by commune

![Graph showing number of people with university degree by commune over time]
Brussels case study

- Logsums for each location
Brussels case study

- Logsum for each location after adjustment of $b_h$
Discussion

- Framework allows for supply or demand surplus
- Changes in (aggregate) market conditions are captured in the price
- Adjustment of $b_h$ produces maximum expect bids close to observed prices
- Scale of prices
  - Arbitrary? (positive or negative $b_h$)
  - Estimation of $\mu$?
  - Should bid’s be also adjusted location-wise ($b_i$)?
  - Relative importance of $b_{hi}$? (re-estimation of betas?)
Further research

- Active bidders (choice set generation)
  - Price is affected by who is “competing” for the location
  - Choice set generation or importance sampling?
  - Relevance of the scale of the logsum

- Location assignment
  - Monte Carlo simulation following max bid probabilities?
  - Simultaneous location assignment?
Thanks
Choice approach for location choice

- Assumptions:
  - Each agent selects the location that provides maximum utility
  - Agents are price takers
  - Prices (usually) defined as function of the location attributes
Choice approach for location choice

- Assumption: consumer surplus is a proxy of utility:
  \[ V_{hi} = B_{hi} - r_i \]

- Probability of location \( i \) providing maximum utility to agent \( h \):
  \[
P_{i/h} = \frac{\exp(\mu(B_{hi} - r_i))}{\sum_j \exp(\mu(B_{hj} - r_j))}
\]
Choice approach for location choice

- Problems:
  - Price-taker assumption (not good for quasi-unique goods)
  - Market conditions usually not captured by hedonic rents

- Advantages:
  - If prices are the outcome of an auction, the location distribution is the same for the bid and choice approaches