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

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Outline

1. Motivation
2. Bid approach for location choice
3. Proposed method
4. Brussels case study
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)~~

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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) → b_h^t

Willingness to pay for attributes → b_{hi}^t

$$b_{hi}^{t} = f(z_{i}^{t-1}, x_{h}^{t}, \beta) \longrightarrow$$ 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:

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

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 : 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:

$$b_h^t = -\ln\left(\sum_{i \in S} \exp\left(b_{hi}^t - r_i^{t-1}\right)\right)$$

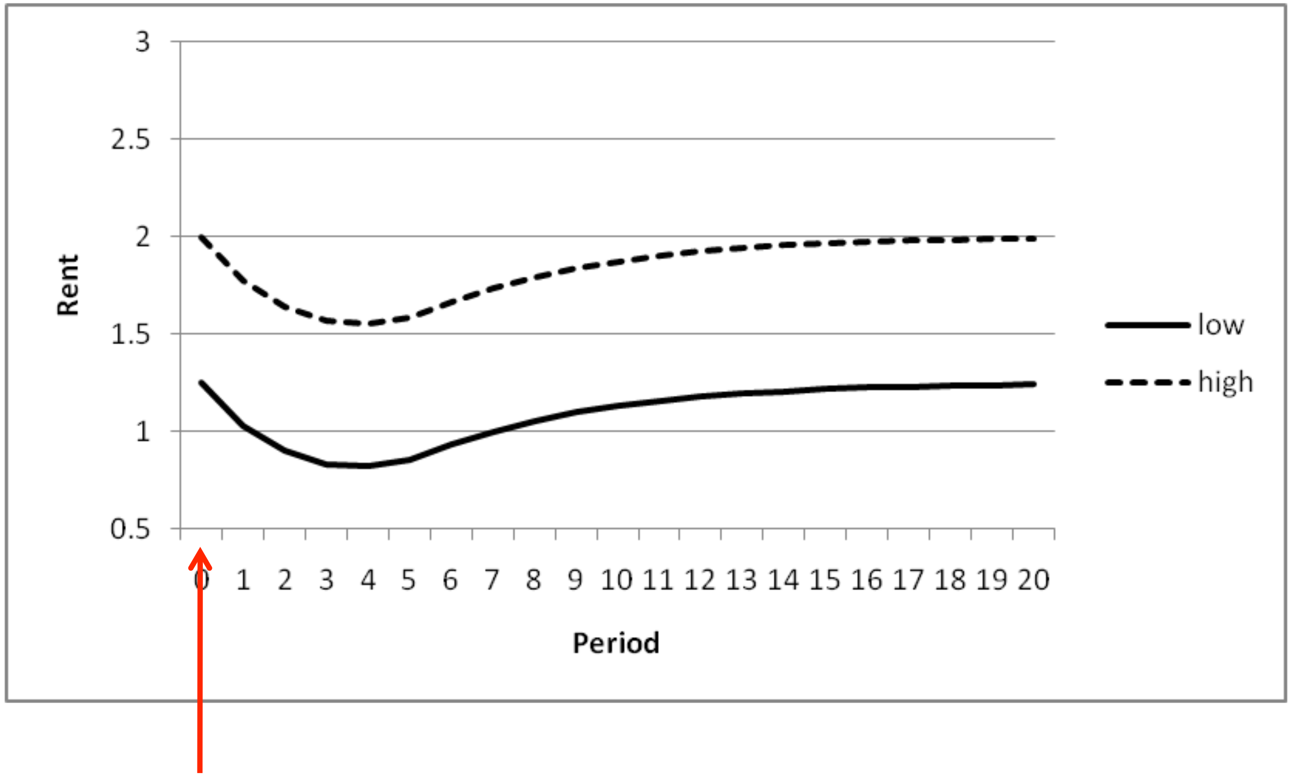
- In the base year (calibration year):

$$b_h^0 = -\ln\left(\sum_{i \in S} \exp\left(b_{hi}^0 - r_i^*\right)\right)$$

Observed prices at the base year

Price dynamics

- Simulation of a supply surplus scenario with synthetic data



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, 1274701dwellings
- 157 communes
- 4975 zones
- 4 types of dwelling
  - Detached houses
  - Semi-detached houses
  - Attached houses

Brussels case study

- Bid function specification:

$$b_{hvi} = \beta_{surf} \cdot surf_{vi} \cdot \ln(N_h) + \beta_{sup} \cdot Q_i^{sup} \cdot N_h^{sup} + \beta_{house} \cdot \lambda_{vi}^{house} \cdot N_h +$$
$$\beta_{trans} \cdot Y_i^{trans} \cdot \gamma_h^{cars=0} + \beta_{trans2} \cdot Y_i^{trans} \cdot \gamma_h^{cars>1} + \beta_{comm} \cdot Y_i^{comm} \cdot \ln(N_h) +$$
$$\beta_{off} \cdot Y_i^{off} \cdot W_h + \beta_{green} \cdot Y_i^{green} \cdot W_h + \ln \phi_h$$

- $surf_{vi}$: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 (accesibility)
- Y_i^{comm}, Y_i^{off}, Y_i^{green} : measurement of the presence of commerce, offices and public green areas
- ϕ_{vi} correction factor for the household-sampling protocol.

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Brussels case study

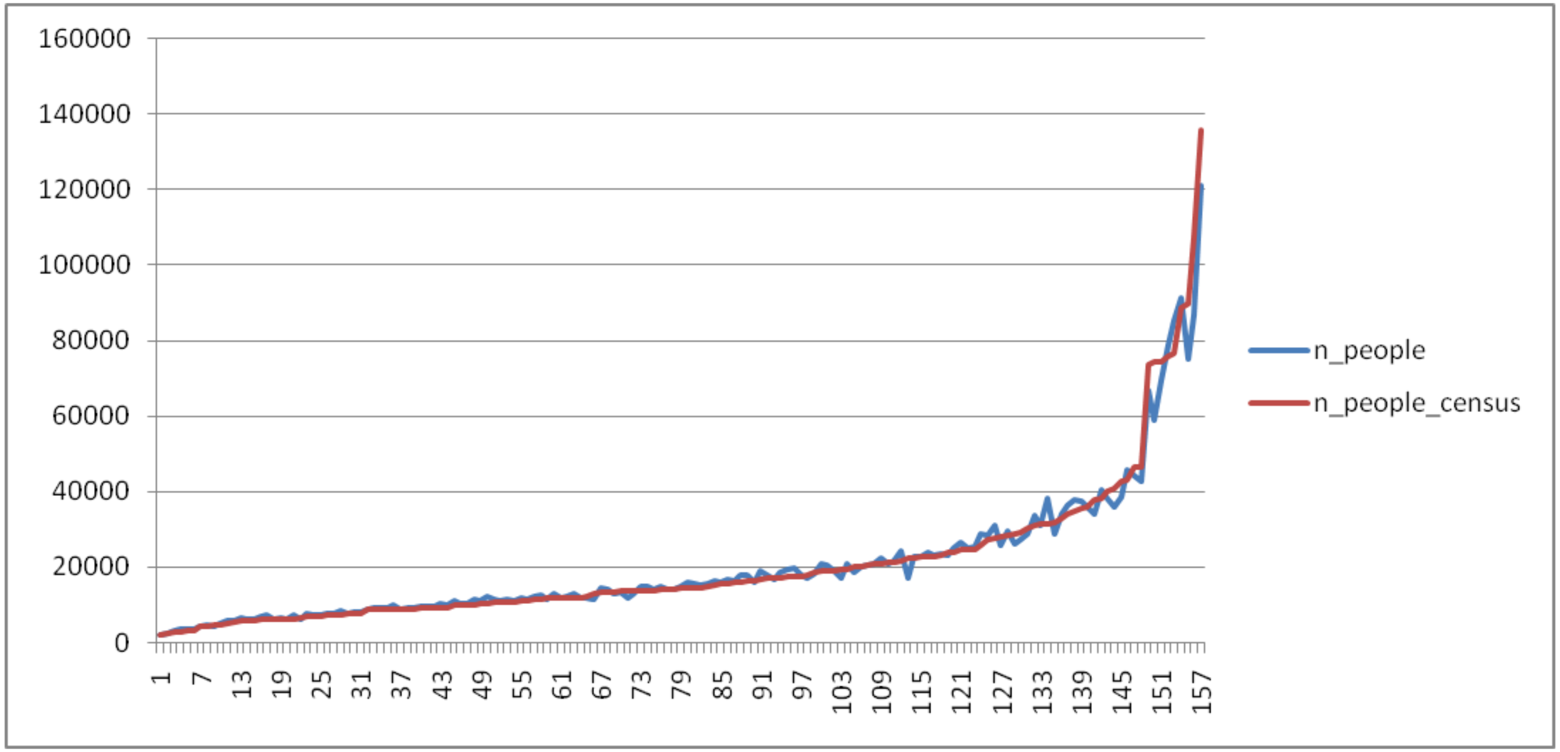
- Estimation results with PythonBiogeme

Name	Value	Std err	t-test	p-value	Robust Std err	Robust t-test	p-value	
B_surf_s	0.00832	0.00265	3.14	0.00	0.00274	3.04	0.00	
B_superior	0.484	0.105	4.62	0.00	0.104	4.63	0.00	
B_trans	0.344	0.138	2.50	0.01	0.144	2.39	0.02	
B_trans2	-0.454	0.157	-2.89	0.00	0.159	-2.87	0.00	
B_house	0.419	0.0622	6.74	0.00	0.0638	6.57	0.00	
B_comm	-1.48	0.286	-5.17	0.00	0.293	-5.05	0.00	
B_green	-0.336	0.0736	-4.57	0.00	0.0771	-4.36	0.00	
B_prof	-0.179	0.0906	-1.98	0.05	0.0933	-1.92	0.05	*

- Likelihood ratio test against null model 219.4

Brussels case study

- Number of people by commune



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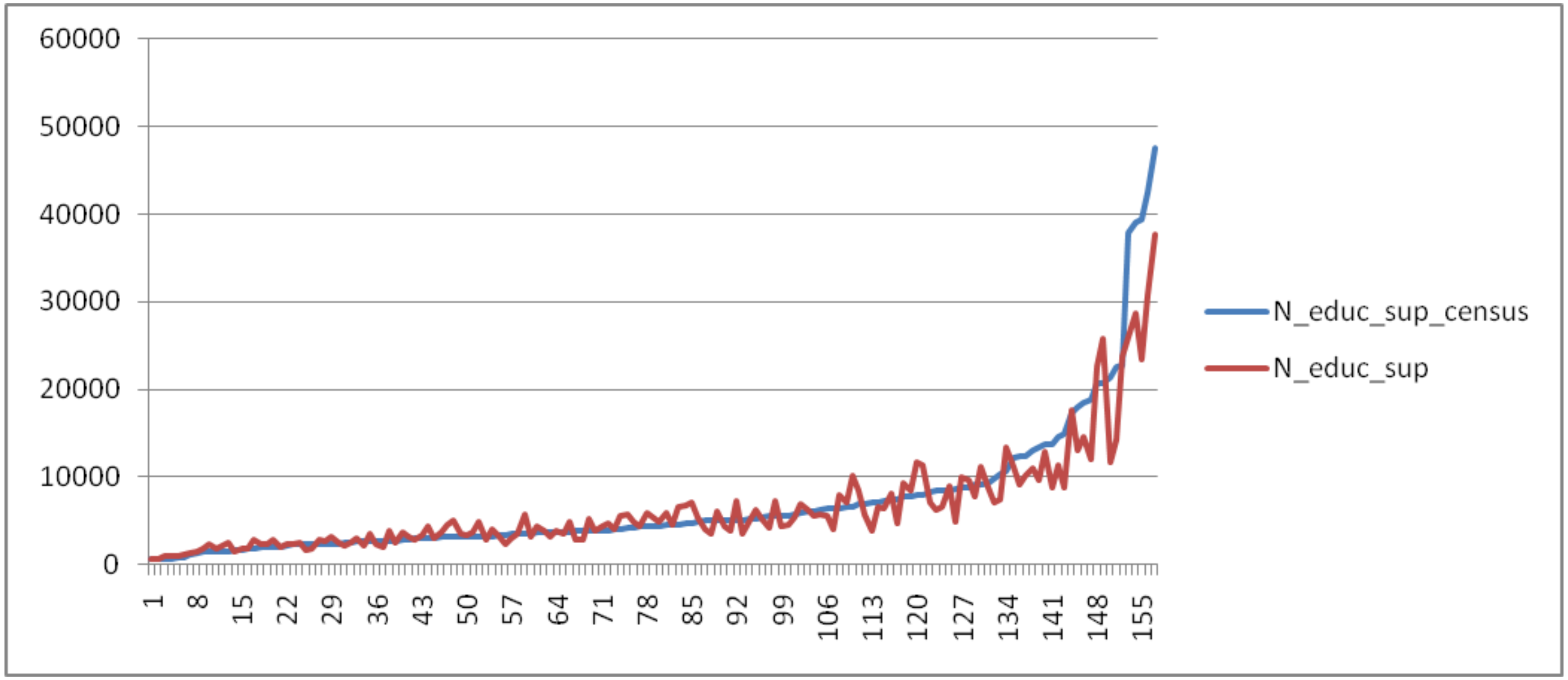
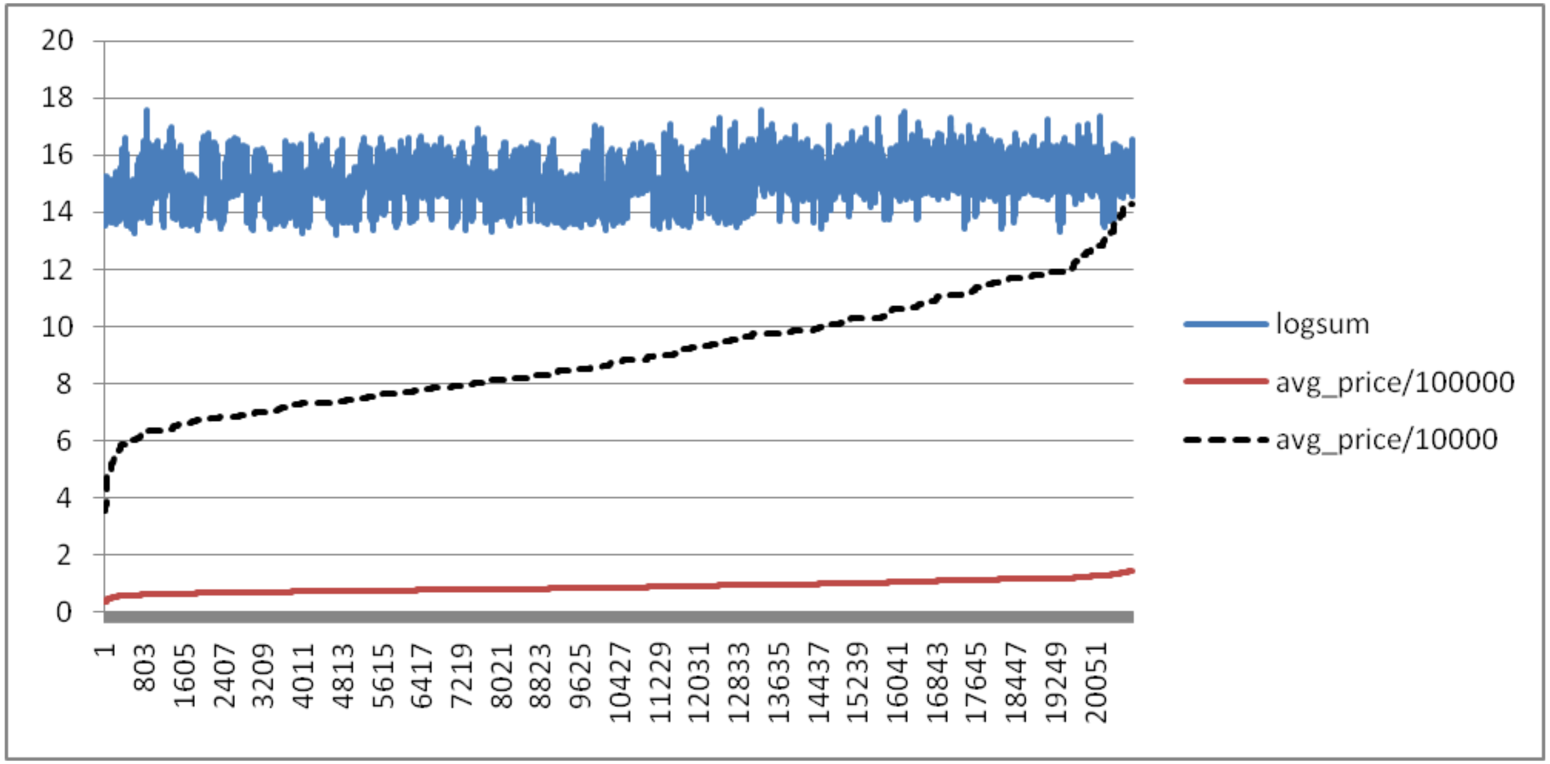
Brussels case study

- Number of people with university degree by commune



Brussels case study

- Logsums for each location



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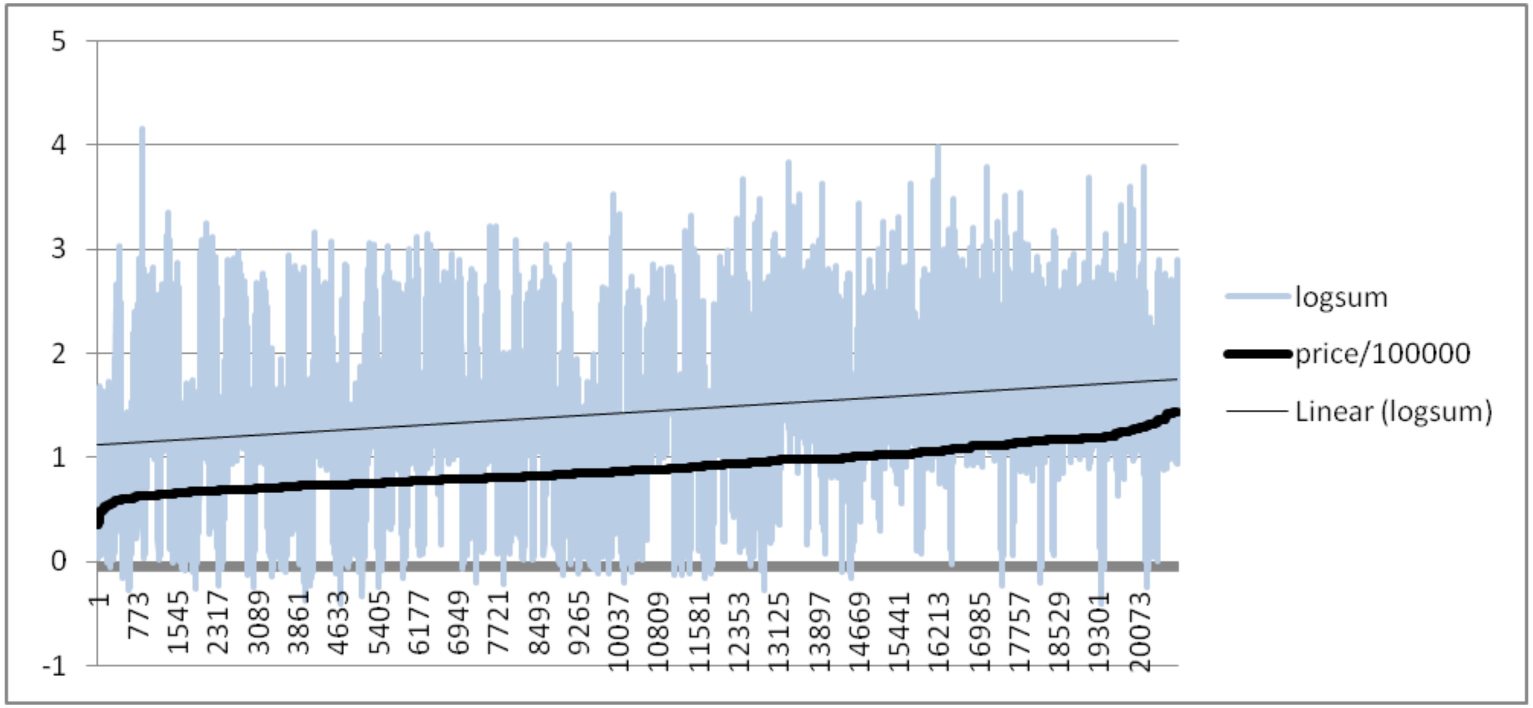
Brussels case study

- 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 μ ?
  - 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