Hierarchical destination choice and spatial interaction modelling a simulation experiment

Peking University Shenzhen Graduate School

Chenglong Wang

Fotheringham A S, Nakaya T, Yano K, et al. Hierarchical destination choice and spatial interaction modelling: a simulation experiment[J]. Environment and Planning A, 2001, 33(5): 901-920.

Production-constrained gravity model

- **Derivation**

  1) Utility (ignore error terms):

$$U(i,j) = \alpha_1 lnS_j + \alpha_2 d_{ij}$$

  2) Probability (Softmax):

$$p_{ij} = S_j^{\alpha_1} exp(\alpha_2 d_{ij})[\sum_q S_q^{\alpha_1} exp(\alpha_2 d_{iq})]^{-1}$$

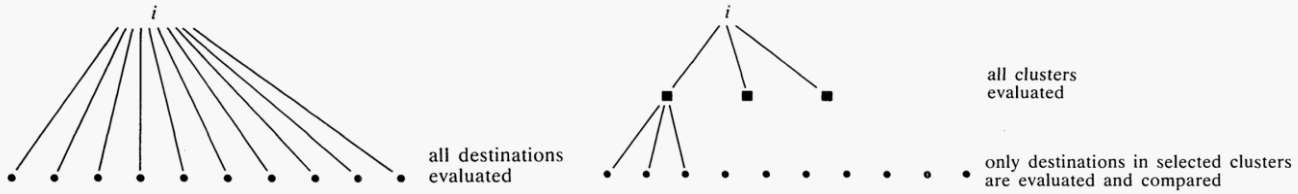
  3) Independence from Irrelevant Alternatives property:

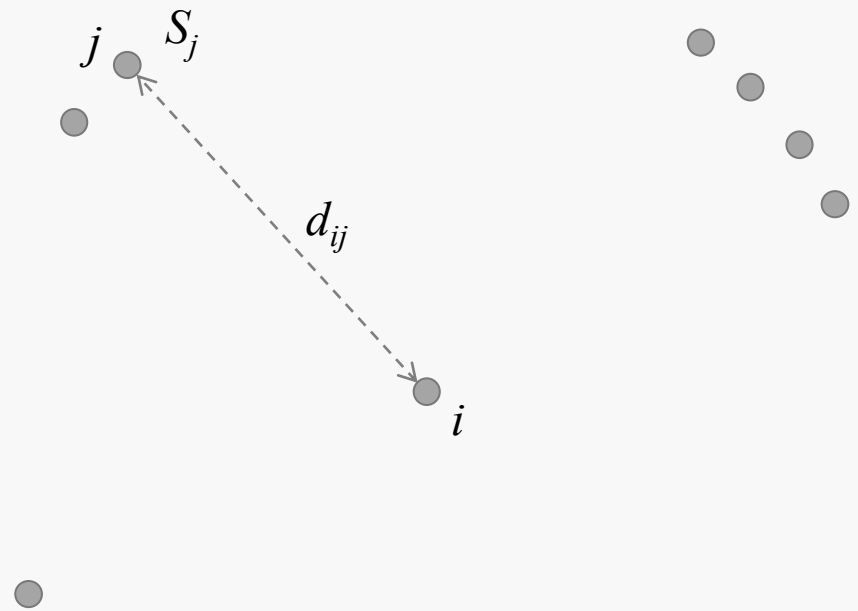
$$p_{is} / p_{it} = S_s^{\alpha_1} exp(\alpha_2 d_{is}) / S_t^{\alpha_1} exp(\alpha_2 d_{it})$$

- **Problems**

  1) Accessibility (Single scale)
  2) Hierarchical destination choice (A spatial hierarchy)

Shopping center - Restaurant





i - *origin*
j - *destination*
d_{ij} - *distance*
S_j - *attribute (Population/Opportunities/...)*

Competing destinations model (Single Scale)

Derivation

1) Utility (ignore error terms):

$$U(i,j) = \alpha_1 lnS_j + \alpha_2 d_{ij} + \alpha_3 lnA_j$$

2) Probability (Softmax):

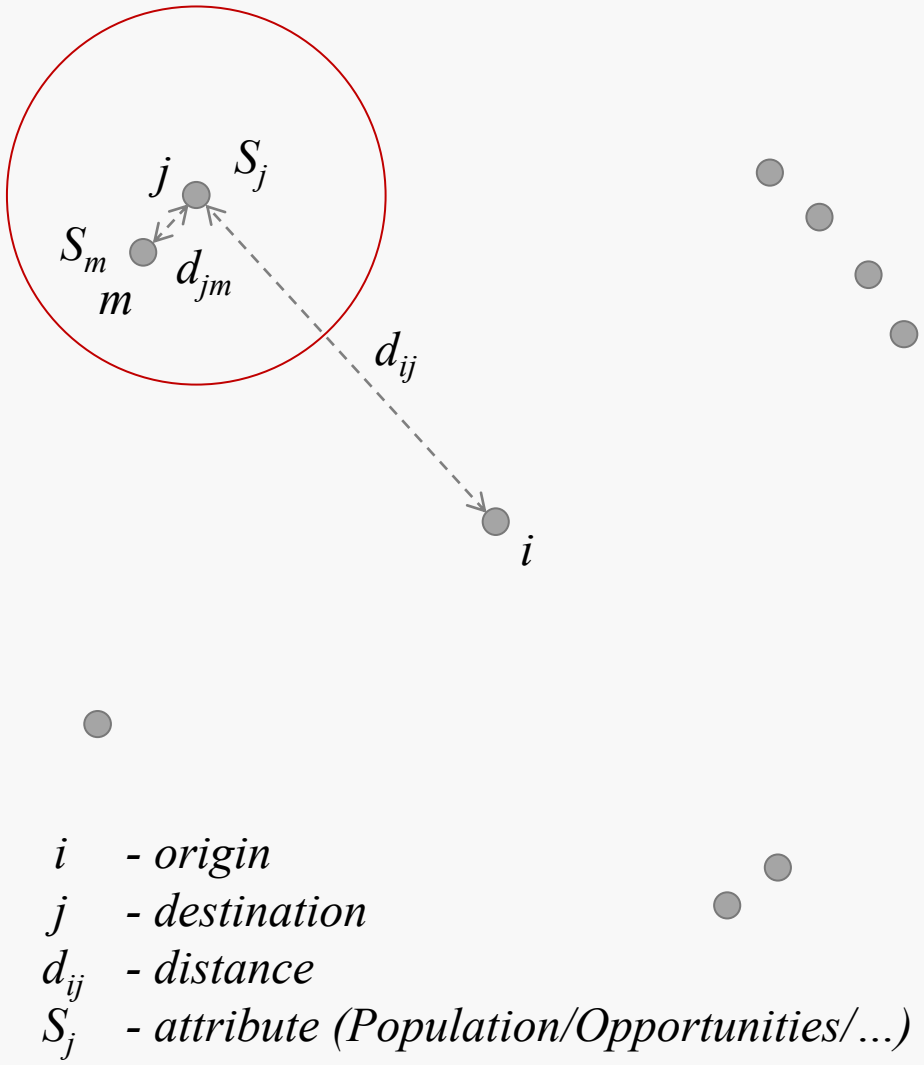
$$p_{ij} = S_j^{\alpha_1} exp(\alpha_2 d_{ij}) A_j^{\alpha_3} [\sum_q S_q^{\alpha_1} exp(\alpha_2 d_{iq}) A_q^{\alpha_3}]^{-1}$$

3) Accessibility:

$$A_j = \sum_{m(m \neq j)} \frac{S_m}{d_{jm}}$$

Property

· A positive value of α_3 – agglomeration forces;
· A negative value of α_3 – competition forces;
· A zero value of α_3 – IIA property.



i - *origin*
j - *destination*
d_{ij} - *distance*
S_j - *attribute (Population/Opportunities/...)*

Hierarchical destination choice

- **Destination choice as a one-stage process**

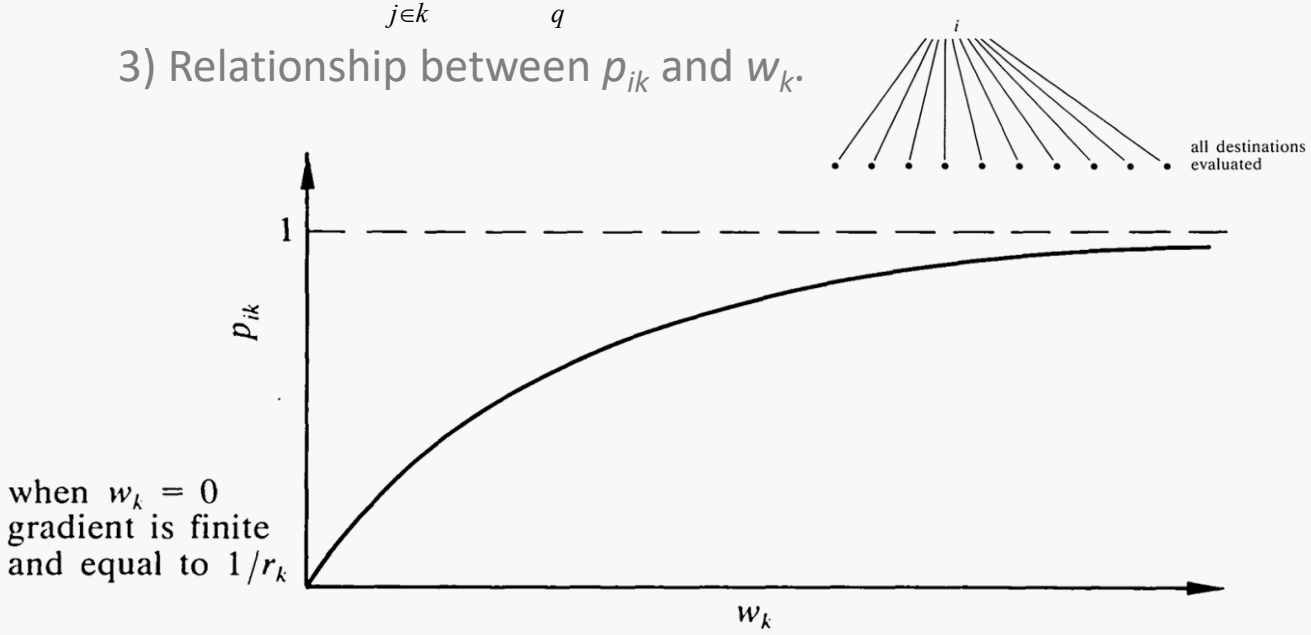
  1) Probability:

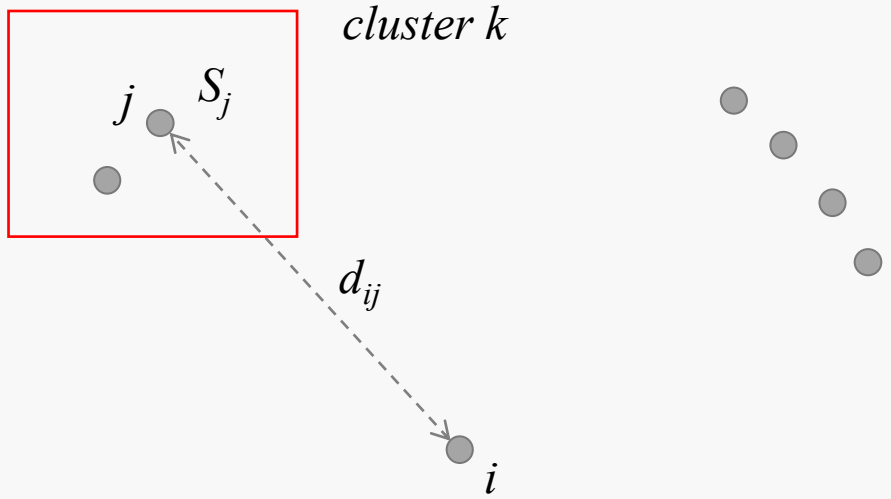
$$p_{ik} = \sum_{j \in k} S_j^{\alpha_1} exp(\alpha_2 d_{ij}) [\sum_q S_q^{\alpha_1} exp(\alpha_2 d_{iq})]^{-1}$$

  2) Simplification:

$$p_{ik} = \sum_{j \in k} S_j^{\alpha_1} [\sum_q S_q^{\alpha_1}]^{-1} = w_k / w_k + r_k$$

  3) Relationship between p_{ik} and w_k.





i - *origin*
j - *destination*
k - *cluster*
d_{ij} - *distance*
S_j - *attribute (Population/Opportunities/...)*

Hierarchical destination choice

- **Destination choice as a two-stage process**

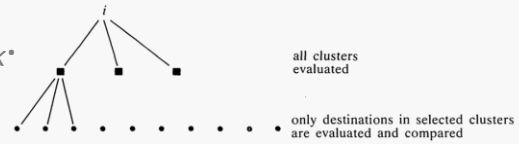
  1) Probability:

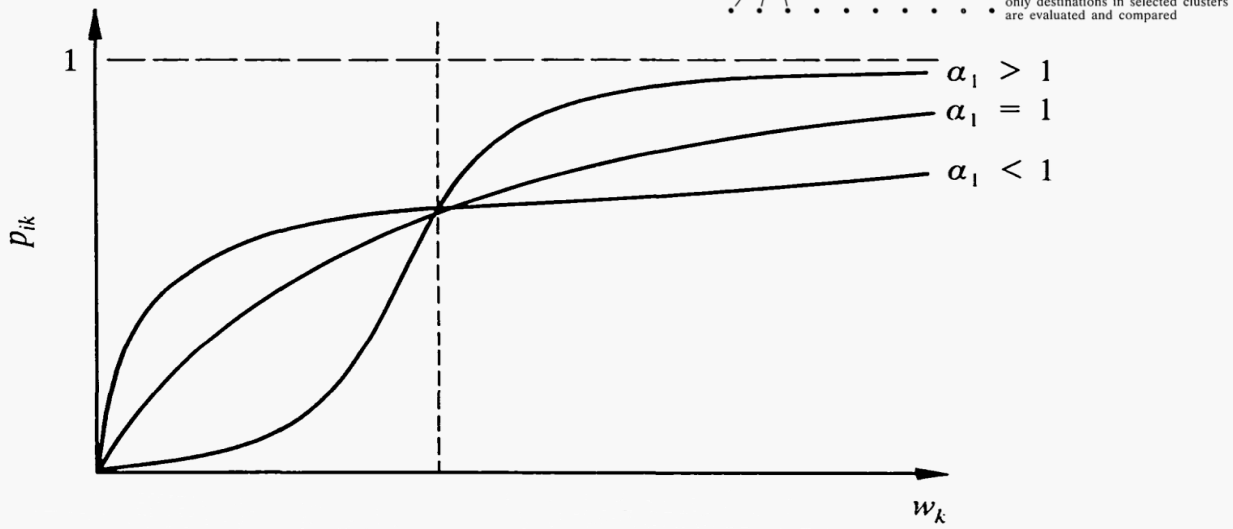
$$p_{ik} = [(\sum_{j \in k} S_j)^{\alpha_1} exp(\alpha_2 d_{ik})][\sum_x (\sum_{j \in x} S_j)^{\alpha_1} exp(\alpha_2 d_{ix})]^{-1}$$

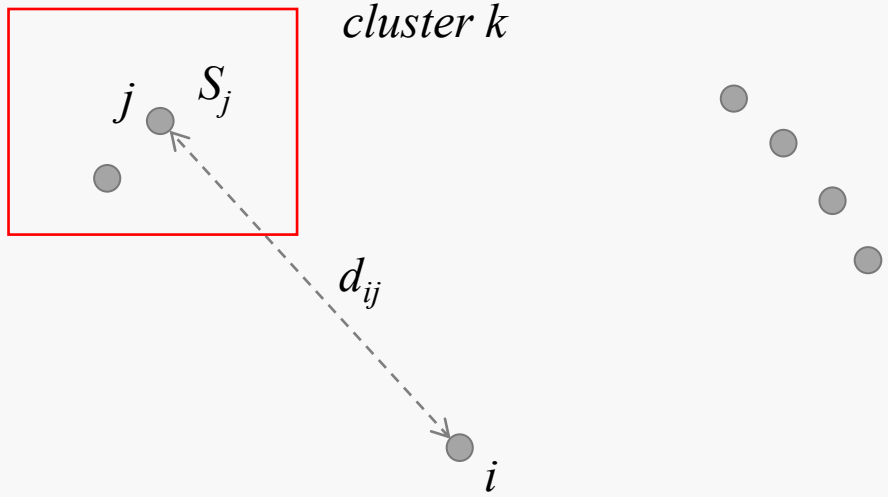
  2) Simplification:

$$p_{ik} = (\sum_{j \in k} S_j)^{\alpha_1} [\sum_x (\sum_{j \in x} S_j)^{\alpha_1}]^{-1} = w_k^{\alpha_1} (\sum_x w_x^{\alpha_1})^{-1}$$

  3) Relationship between p_{ik} and w_k.







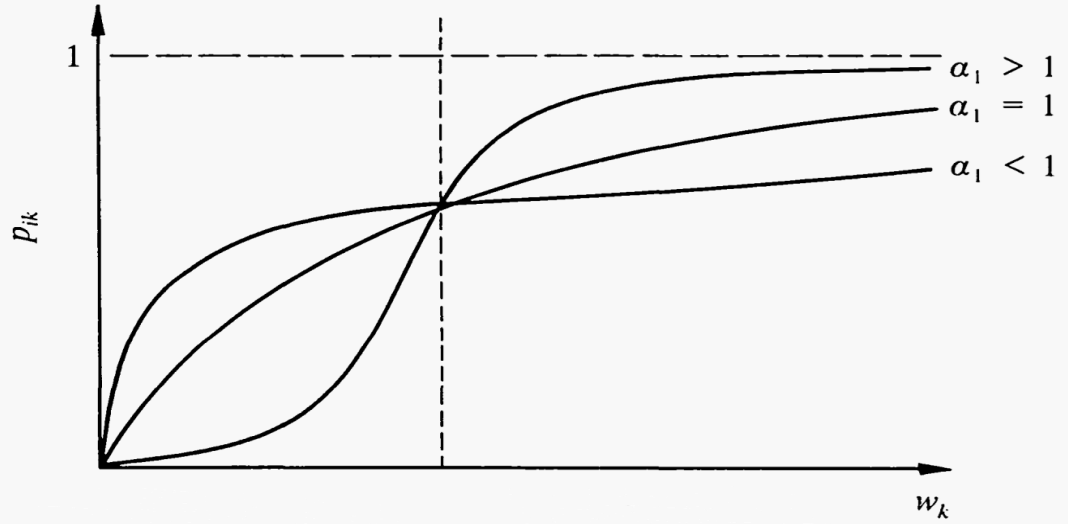
i - *origin*
j - *destination*
k - *cluster*
d_{ij} - *distance*
S_j - *attribute (Population/Opportunities/...)*

Hierarchical destination choice

Gravity model – systematic errors

1) When $\alpha_1 > 1$, the gravity model would ***overpredict*** the probability of an individual selecting ***a small cluster of destinations***, and would ***underpredict*** the probability of an individual selecting ***a large cluster of destinations***.

2) Conversely, when $\alpha_1 < 1$, the gravity model would ***underpredict*** the probability of an individual selecting ***a small cluster of destinations***, and would ***overpredict*** the probability of ***selecting a large cluster***.



Difficulty & Similarity

$$p_{ik} = [(\sum_{j \in k} S_j)^{\alpha_1} exp(\alpha_2 d_{ik})][\sum_x (\sum_{j \in x} S_j)^{\alpha_1} exp(\alpha_2 d_{ix})]^{-1}$$

cluster k

$$p_{ij} = S_j^{\alpha_1} exp(\alpha_2 d_{ij}) A_j^{\alpha_3} [\sum_q S_q^{\alpha_1} exp(\alpha_2 d_{iq}) A_q^{\alpha_3}]^{-1}$$

$$p_{ik} = [(\sum_{j \in k} S_j)^{\alpha_1} exp(\alpha_2 d_{ik})][\sum_x (\sum_{j \in x} S_j)^{\alpha_1} exp(\alpha_2 d_{ix})]^{-1}$$

Destination choice process	α_1	α_3
One-stage	-	0
Hierarchical	>1	>0
Hierarchical	1	0
Hierarchical	<1	<0

Gravity model – Competing destinations model – Simulation – QA

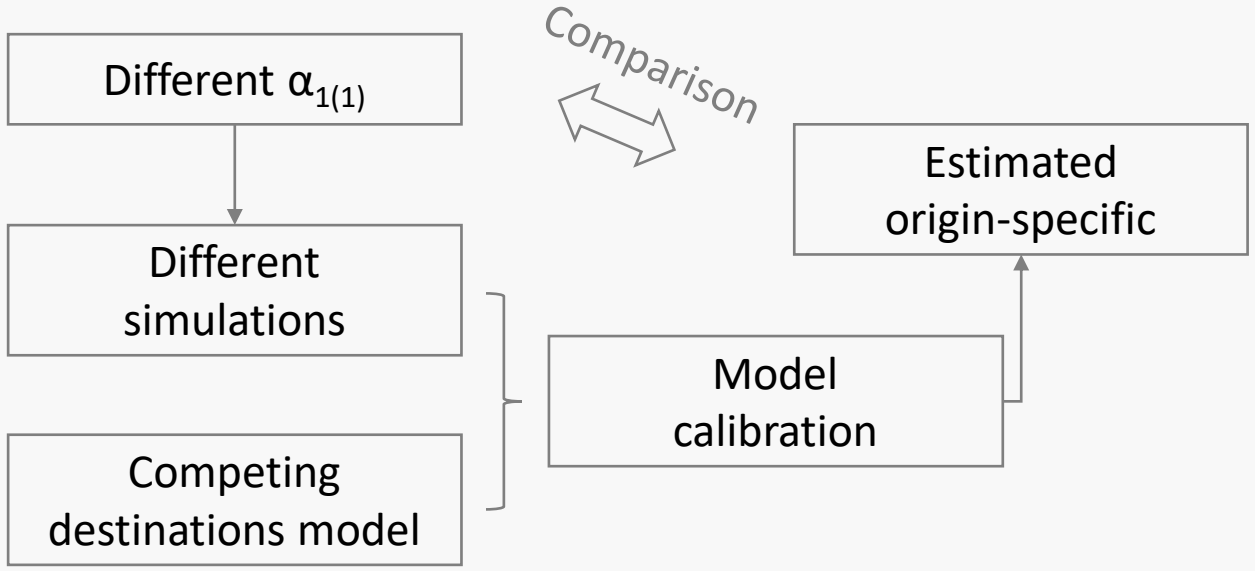
Simulation Steps

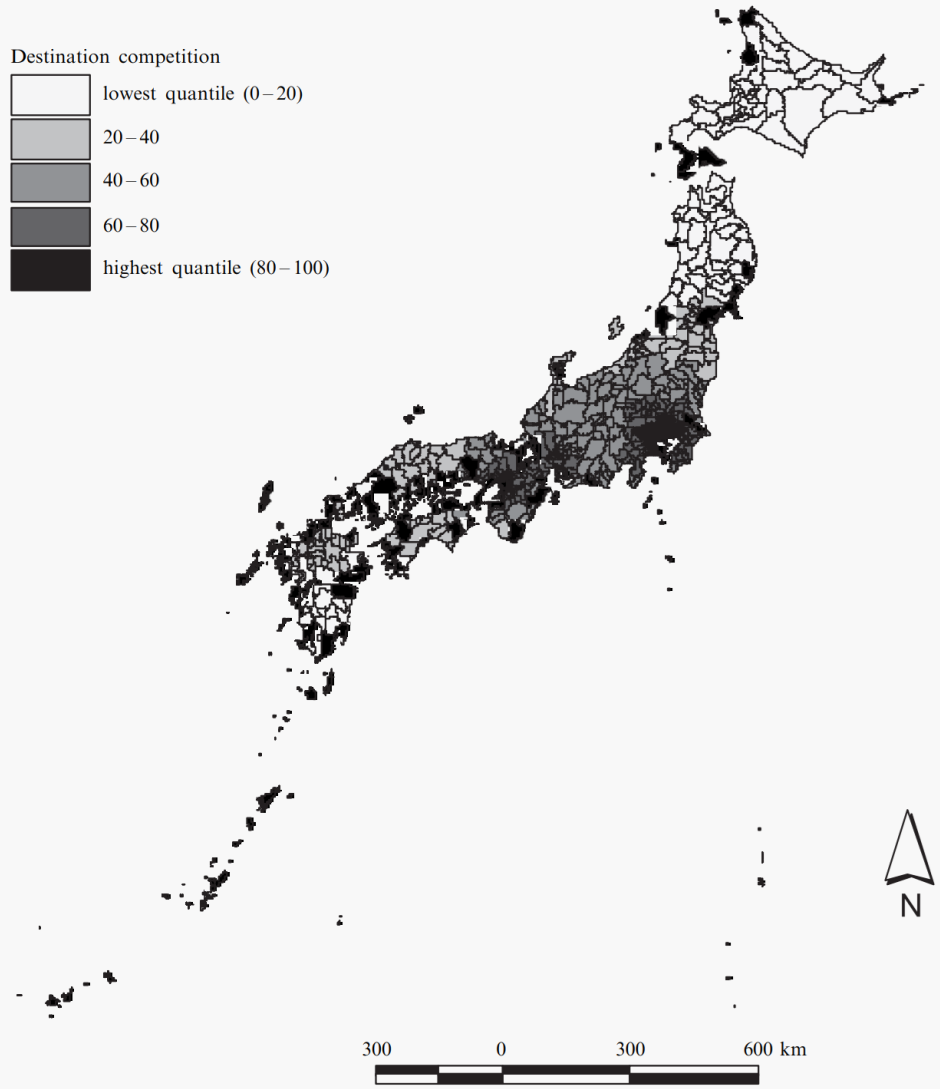
- **Step 1: simulating level-1 choice behaviour(109 area zones)**

$$p_{ik} = [(\sum_{j \in k} S_j)^{\alpha_{1(1)}} exp(\alpha_{2(1)} d_{ik})][\sum_{x} (\sum_{j \in x} S_j)^{\alpha_{1(1)}} exp(\alpha_{2(1)} d_{ix})]^{-1}$$

- **Step 2: simulating level-2 choice behaviour(727 city zones)**

$$p_{ij} = p_{ik}[S_j^{\alpha_{1(2)}} exp(\alpha_{2(2)} d_{ij})][\sum_{q \in k} S_q^{\alpha_{1(2)}} exp(\alpha_{2(2)} d_{iq})]^{-1}$$





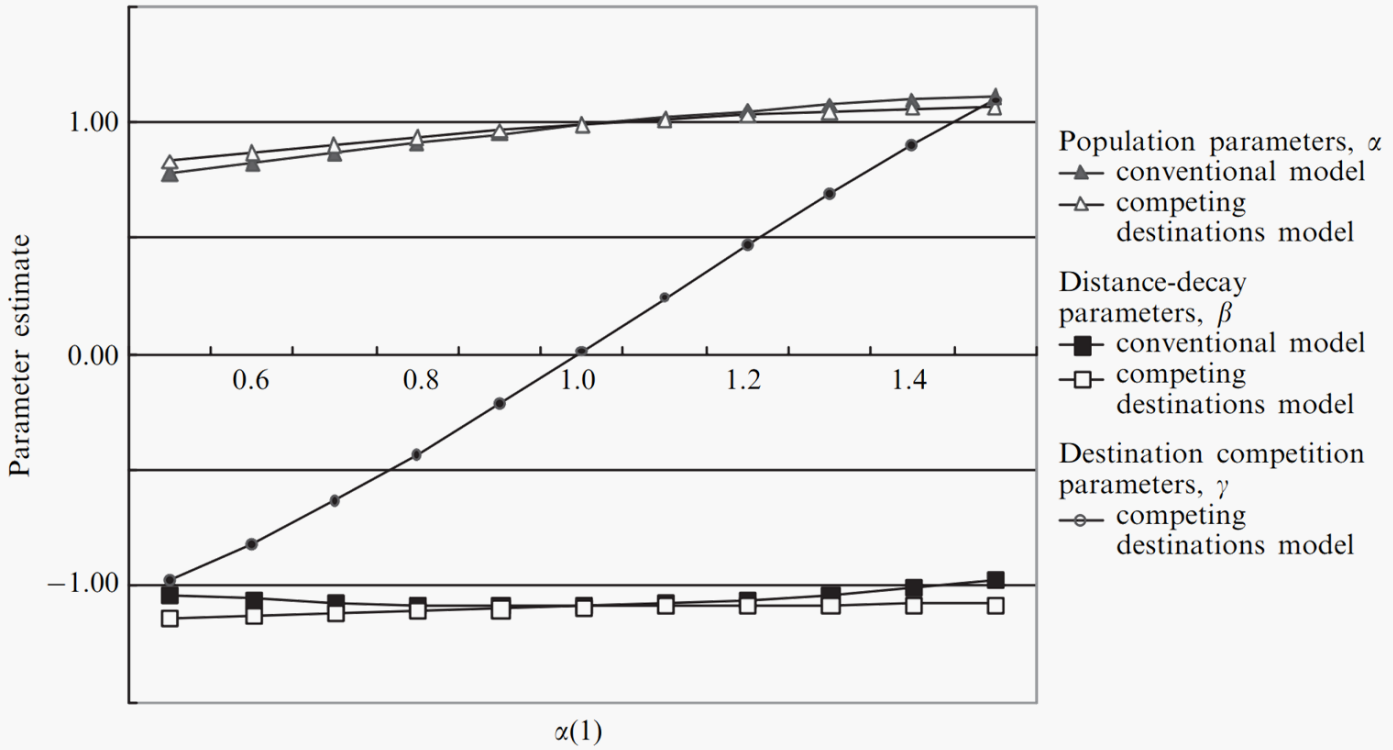
Gravity model – Competing destinations model – Simulation – QA

Results

- **Questions:**

*1) Can the competing destinations model really account for **hierarchical destination choice** or is the significance of the competing destinations variable when applied to real interaction data **merely a reflection of migrants' preferences regarding the spatial agglomeration of distances**?*

*2) Can the competing destinations model be used to provide information on different types of hierarchical information processing? Is it robust enough to capture **both agglomeration effects and competition effects**?*

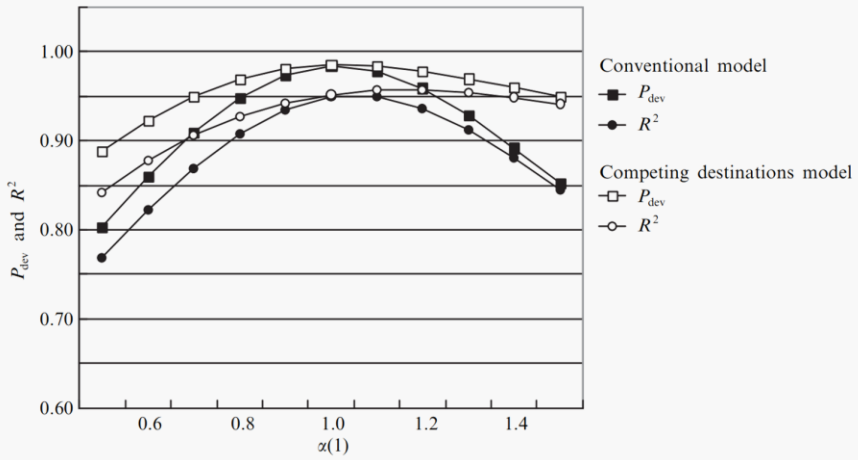


Gravity model – Competing destinations model – Simulation – QA

Results

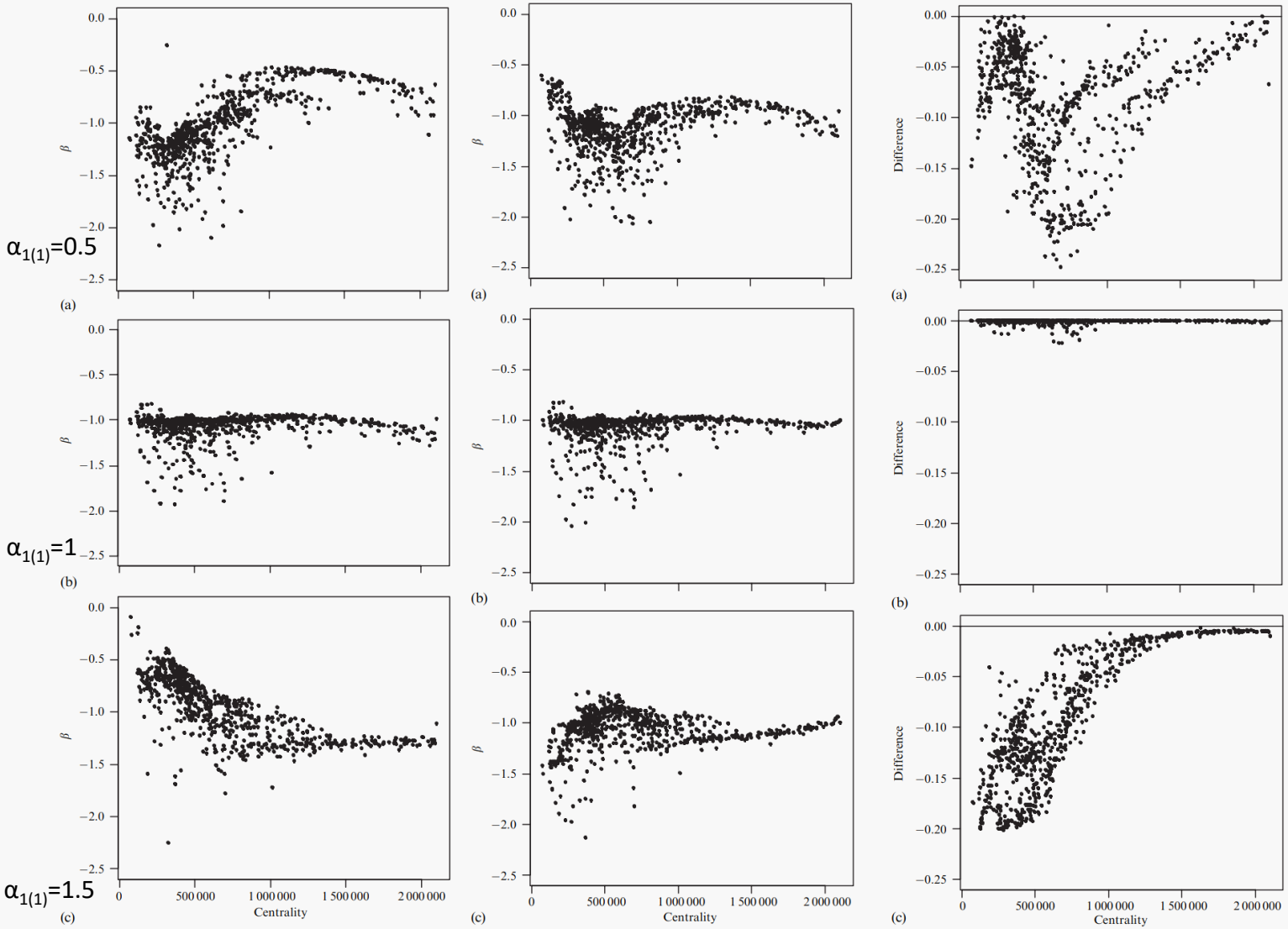
- **Questions:**

3) How does agglomeration effects and competition effects manifest themselves in terms of the outputs from both the conventional spatial interaction model and the competing destinations model?



Estimated distance-decay parameters

Percentage deviance explained statistic



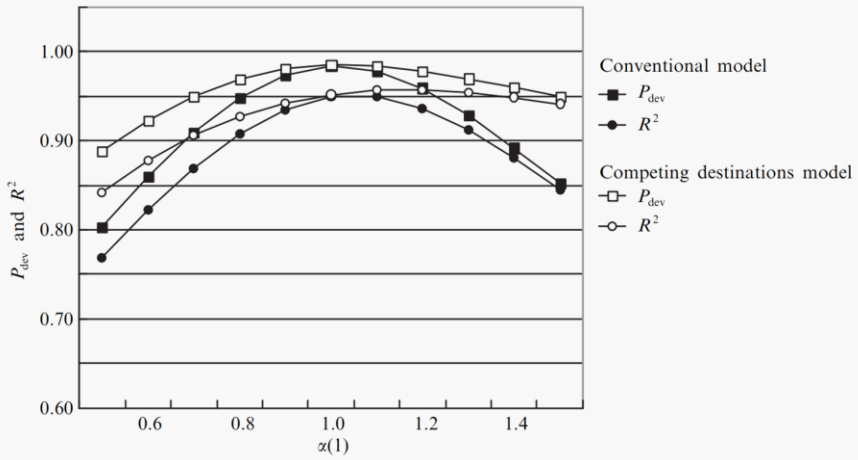
Gravity | Competing | Competing - gravity

Gravity model – Competing destinations model – Simulation – QA

Results

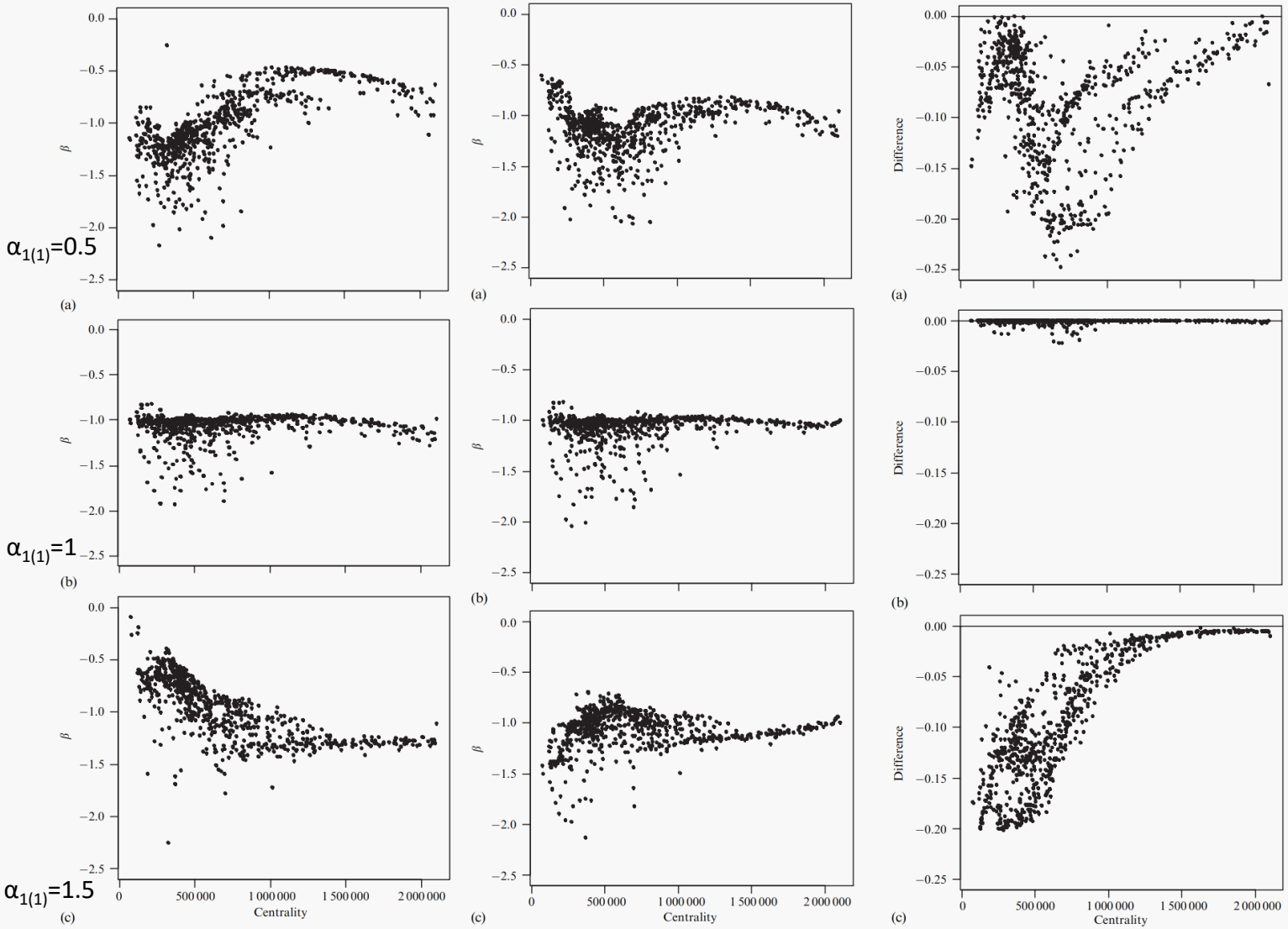
- **Questions:**

4) What happens if the competing destinations model is applied to a flow matrix where the destination choices are not made hierarchically? Does it yield the same parameter estimates as a conventional model?



Estimated distance-decay parameters

Percentage deviance explained statistic

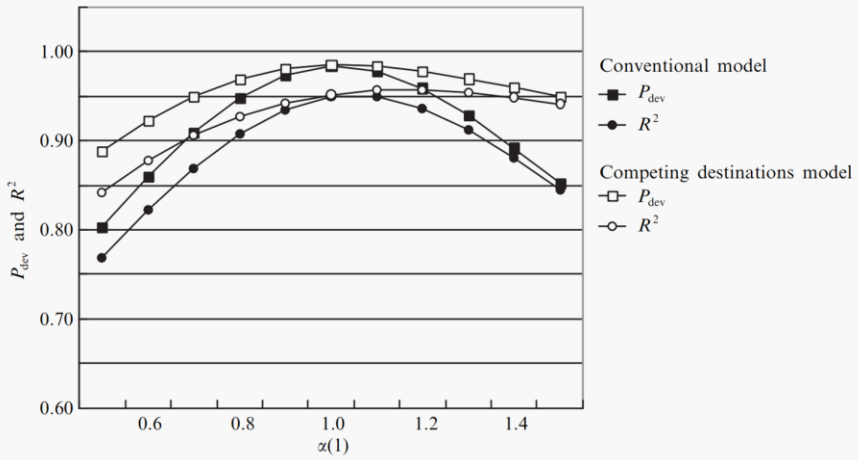


Gravity model – Competing destinations model – Simulation – QA

Results

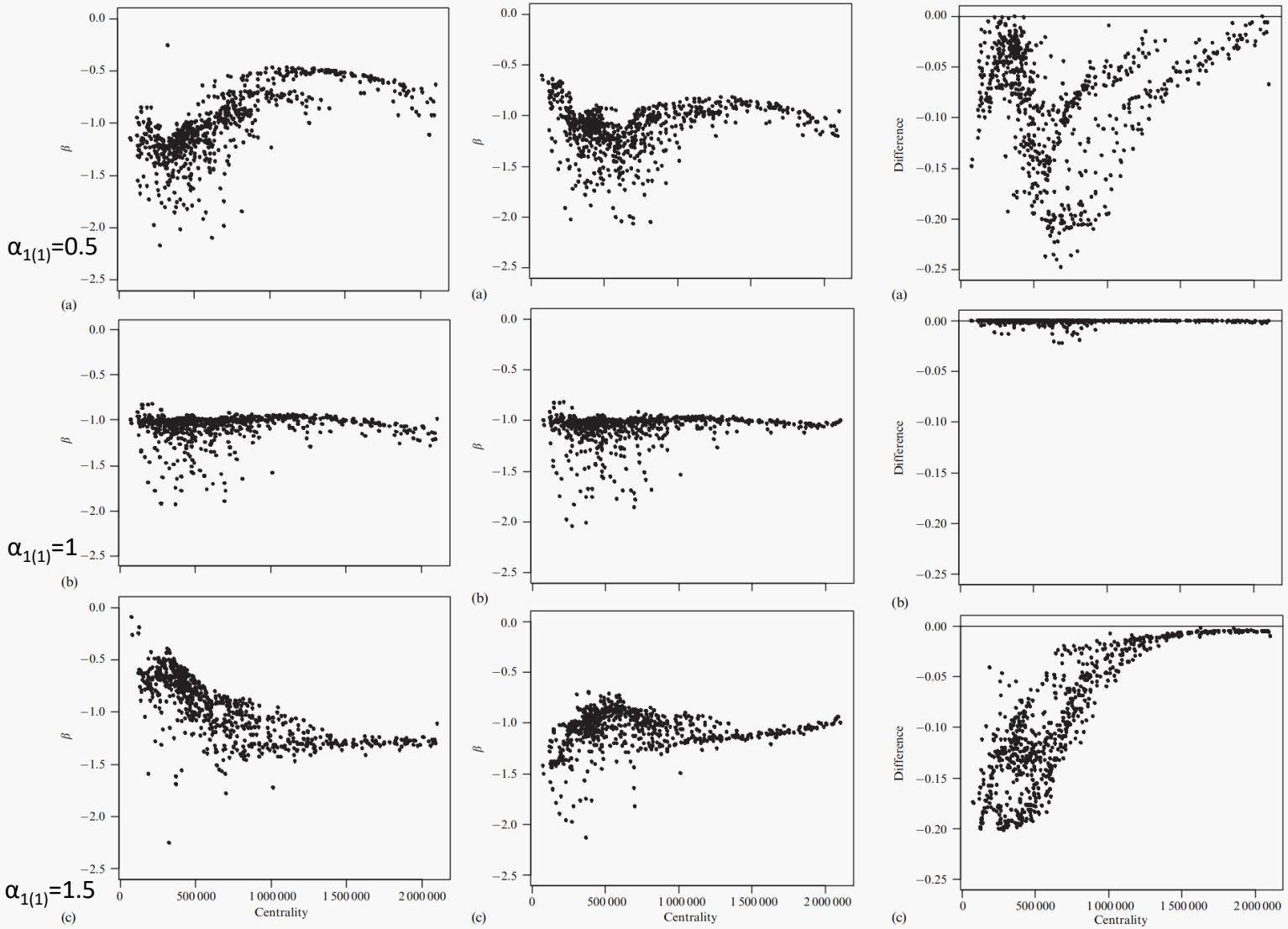
- **Questions:**

5) What happens, for instance, when there is no hierarchical choice – does the model still produce superior estimates?



Estimated distance-decay parameters

Percentage deviance explained statistic



Gravity model – Competing destinations model – Simulation – QA

Critical Review

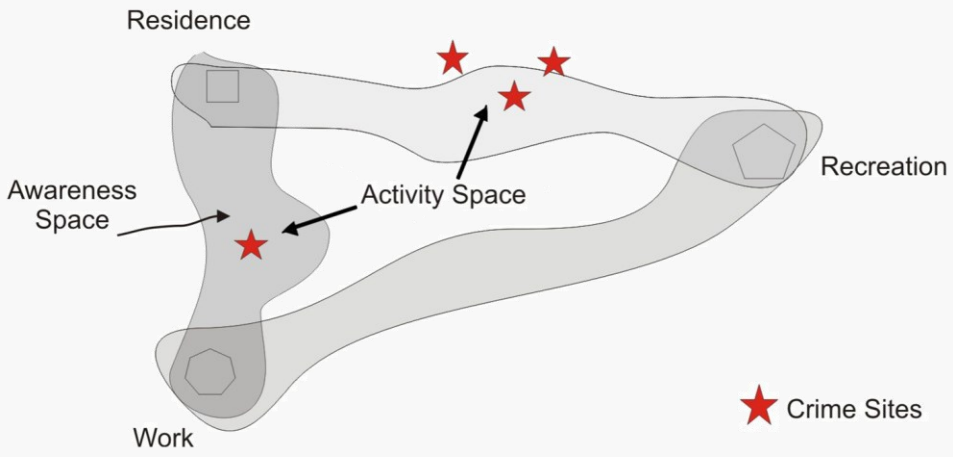
- **Opinions:**

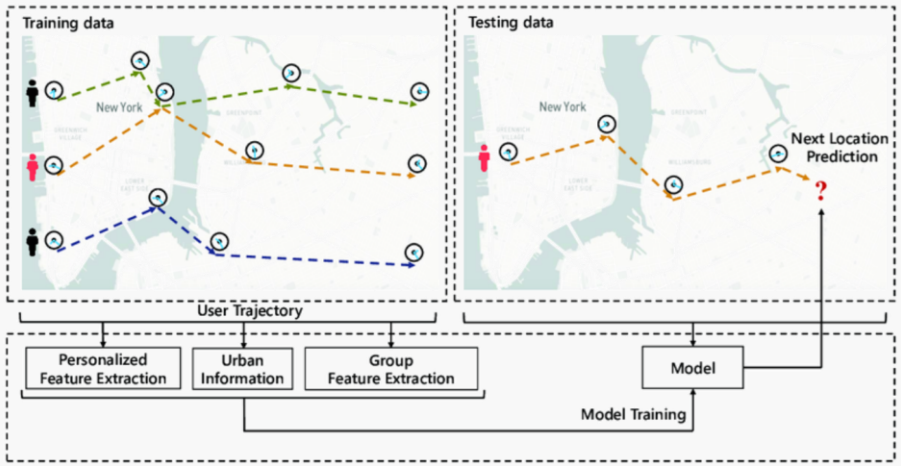
1) **Experiment?**
   - More regions, more levels, more attributes?
   - Simulation is all you need.

$$p_{ij} = \frac{V_{1j}^{\alpha_1} V_{2j}^{\alpha_2} \cdots V_{nj}^{\alpha_n} d_{ij}^{\beta}}{\sum_j V_{1j}^{\alpha_1} V_{2j}^{\alpha_2} \cdots V_{nj}^{\alpha_n} d_{ij}^{\beta}}$$

2) **Innovation:**
   - Modeling ≠ Reality -> a spatial hierarchy;
   - Geo for AI, spatially explicit artificial intelligence. (Next location prediction)

3) **Future research:**
   - Search for evidence of hierarchical decisionmaking in destination choice;
   - Application (crime/education/…).





Hierarchical destination choice and spatial interaction modelling a simulation experiment

Peking University Shenzhen Graduate School

Chenglong Wang

Fotheringham A S, Nakaya T, Yano K, et al. Hierarchical destination choice and spatial interaction modelling: a simulation experiment[J]. Environment and Planning A, 2001, 33(5): 901-920.