Disaggregate simulation and some implications for calibration

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An appeal for a more disaggregate perspective

- common sense is to "keep things simple"
- increased disaggregation
  - looks more at the "distributed" side of a simulation
  - may appear as if one was not keeping things simple
- this talk indicates **relevance** and **feasibility** of disaggregation

One argument: calibration principles stay clear

- calibration problem statement:

$$P(\mathbf{X} \mid \mathbf{Y}) \propto P(\mathbf{Y} \mid \mathbf{X}) P(\mathbf{X})$$

- naive simulation of the solution:

$$\begin{aligned} \mathrm{E}\{\mathbf{X} \mid \mathbf{Y}\} &\propto \int \mathbf{X} P(\mathbf{Y} \mid \mathbf{X}) P(\mathbf{X}) d\mathbf{X} \\ &\approx \frac{1}{R} \sum_{r=1}^{R} \mathbf{X}^r P(\mathbf{Y} \mid \mathbf{X}^r); \quad \mathbf{X}^r \sim P(\mathbf{X}) \end{aligned}$$

- It *is* possible to do things like this for very large systems!

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Outline

Relevance: truthful modeling of uncertainty

Doability: avoiding to drown in details

Summary

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Explaining deviations from reality

- when calibrating a (complicated) microsimulation...
  - one needs some kind of **calibration model**
  - this model must explain all deviations from reality
- essentially two approaches:
  1. use a deterministic calibration model[1] and add random slack
  2. explicitly use a stochastic model to represent uncertainty

[1] assignment matrix, OD matrix, linear dynamics, response surface, ...

Deterministic calibration model + random slack?

- (typical) measurement equation:

$$\mathbf{Y} = F(\mathbf{X}_1) + \varepsilon(\mathbf{X}_2)$$

- two extreme cases
  1. analyst really knows what is going on: $\mathbf{Y} = F(\mathbf{X}_1)$
  2. analyst does not get the causality right: $\mathbf{Y} = \varepsilon(\mathbf{X}_2)$
- in transportation, one seems to deal more with case 2...

Example: choice set uncertainties

- (simulated) travel behavior with uncertain choice sets:

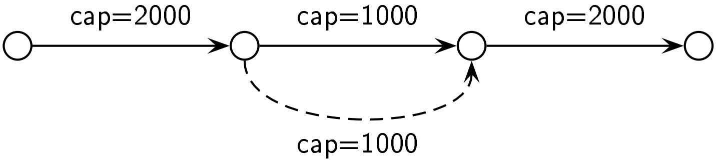
$$P_n(i) = \sum_{\mathcal{C}_n \in \mathcal{C}} P_n(i \mid \mathcal{C}_n) P_n(\mathcal{C}_n)$$

- operational version:

$$P_n(i) = P_n(i \mid \mathcal{C})$$

- not allowing for all alternatives can lead to inconsistencies
  - well known in choice modeling
  - have never seen this in OD matrix estimation

Things can go wrong in the simplest case



- scenario:
  - peak hour demand of 1500 exceeds each route alone
  - congestion builds up *upstream* of the diverge

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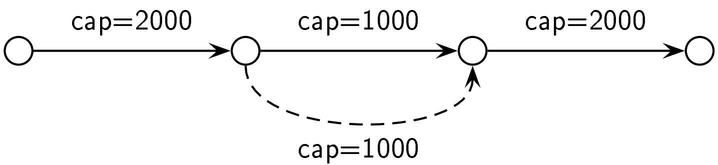

- scenario:
  - peak hour demand of 1500 exceeds each route alone
  - congestion builds up *upstream* of the diverge
- best-response choice set generation *never* finds the detour
- even with a stochastic choice model, *no one* takes the detour
- effect on OD/path flow estimation when using random slacks?!

Metropolis-Hastings sampling of paths (1/2)

- approach
  - give every path $i \in \mathcal{C}$ a weight $b(i) > 0$
  - sampling probability $q(i)$ shall be $\propto b(i)$
- direct sampling from $q(i)$ requires path enumeration

$$q(i) = \frac{b(i)}{\sum_{j \in \mathcal{C}} b(j)}$$

- MH does the job based on pair-wise comparisons only

$$\frac{q(i)}{q(j)} = \frac{b(i)}{b(j)}$$

Metropolis-Hastings sampling of paths (2/2)

[[movie]][2]

[2] Flötteröd & Bierlaire (submitted).
`transp-or.epfl.ch/documents/technicalReports/FloeBier11.pdf`

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Where this is going

- this talks suggests to simulate and calibrate more "details"
- here: an idea of how a "gradual enrichment" is possible
  - first, introduce disaggregation without additional modeling
  - second, exploit the resulting structure whenever convenient

Example: dynamic OD matrix estimation

- well-known to be utterly underspecified
- "macroscopic" approaches to deal with this:
  - non-negativity constraints
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  - assume (linear) dynamics
- problems arise when facing:
  - rigorous mass conservation
  - truthful representation of demand fluctuations
  - more than a handful of commodities

Autoregressive OD matrix dynamics

- autoregressive model for OD flows (simplified):

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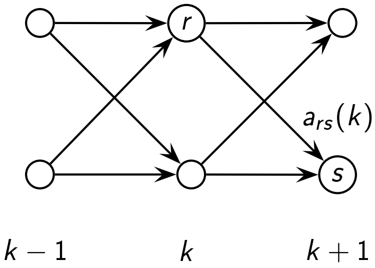
- looking back at the original problem:

$$\Leftarrow \quad \forall n : \quad P_n(s|k+1) = \sum_r a_{rs}(k) P_n(r|k)$$

Really more complex than the AR model?



- Markovian trip making dynamics at individual level
- truthful representation of original AR model
- but...

Added value of traveler disaggregation

- constraints become simple in the disaggregate approach:
  - rigorous mass conservation
  - truthful representation of demand fluctuations
  - more than a handful of commodities
- in addition, one can add any behavioral model of trip chaining
- in this particular example, all of this is already possible[3]

[3] Flötteröd & al. (2011). *Transp. Science*.

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- disaggregate simulation & calibration modeling
  - capture uncertainty where it occurs
  - contribute to unbiased calibration
- model complexity does not necessarily explode
  - in the 1st instance, only add physically existing structure
  - in the 2nd instance, add more complex model structure
- (very subjective) conclusion
  - calibration models benefit from increased disaggregation
  - possible without jumping right on activity-based models