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# 2. Uncertainty propagation and inference


UNIVERSITY OF CAMBRIDGE

**Special Session**
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25–29 June 2017, Chicago, USA

# Methods for MFA

| Method | E. Müller et al (2014) |
|---|---|
| No uncertainty | 52% |
| Sensitivity analysis | 37% |
| Interval analysis | 6% |
| Gaussian propagation (STAN) | 5% |
| Monte Carlo (MMFA, PMFA) | 0% |
| Possibility theory | |

Laner, David, Helmut Rechberger, and Thomas Astrup. 'Systematic Evaluation of Uncertainty in Material Flow Analysis'. Journal of Industrial Ecology 18, no. 6 (2014).

Müller, Esther, Lorenz M. Hilty, Rolf Widmer, Mathias Schluep, and Martin Faulstich. 'Modeling Metal Stocks and Flows: A Review of Dynamic Material Flow Analysis Methods'. Environmental Science & Technology 48, no. 4 (2014).

# Uncertainty & variability in LCA

**Table 2:** Overview of tools available to address types of uncertainty and variability in LCAs

| Tools \ Types | Parameter uncertainty | Model uncertainty | Uncertainty due to choices | Spatial variability | Temporal variability | Variability in objects/sources |
|---|---|---|---|---|---|---|
| Probabilistic simulation | + | | | | | + |
| Correlation and regression analysis | + | | | | | + |
| Additional measurements | + | | | | | + |
| Scenario modelling | | | + | | + | |
| Standardisation | | | + | | | |
| Expert judgement/peer review | + | | + | | | + |
| Non-linear modelling | | + | | | | |
| Multi-media modelling | | + | | + | | |

Huijbregts, Mark A. J. 'Application of Uncertainty and Variability in LCA'. The International Journal of Life Cycle Assessment 3, no. 5 (1998): 273.

Lloyd, Shannon M., and Robert Ries. 'Characterizing, Propagating, and Analyzing Uncertainty in Life-Cycle Assessment: A Survey of Quantitative Approaches'. Journal of Industrial Ecology 11, no. 1 (2007): 161–79.

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**Similar methods to MFA**


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# Uncertainty & variability in IOA

Wiedmann (2009):

- data uncertainty (surveys, trade statistics)
- model assumptions
- production technology of imports (SRIO)
- aggregation & sector concordance, exchange rates, ROW (MRIO)

Parameter uncertainty:

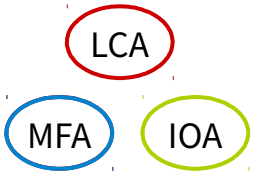
- Monte Carlo

Wiedmann, Thomas. 'A Review of Recent Multi-Region Input–output Models Used for Consumption-Based Emission and Resource Accounting'. Ecological Economics, Special Section: Analyzing the global human appropriation of net primary production - processes, trajectories, implications, 69, no. 2 (2009): 211–22.

# Aims of uncertainty propagation

- Given uncertain data, how uncertain are our results?
- Given conflicting sources, which should we choose?
  (too much data)
- With poor/missing data, how can we use uncertainty as a placeholder to give tentative results?
  (too little data)
- How does model uncertainty affect uncertainty in results?

# Propagating uncertainty




Possibilities

Monte Carlo

Gaussian/ standard errors

Scenarios

Laner et al (2015)

Dubois et al (2014)

Džubur et al (2017)

?

Fuzzy sets & intervals

LCA w/ MC

IOA w/ MC

MFA w/ MC

Bayesian

Bayesian

Lupton & Allwood (2017)

Cencic & Frühwirth (2015)

*RAS, constrained opt.

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Pauliuk et al (2013)

Alternatives

Too little data

Just right

Conflicting data

Model & scenario uncertainty

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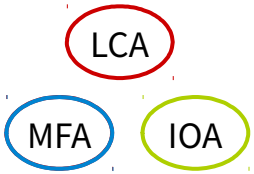


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# Too little data:
# uncertainty as a placeholder

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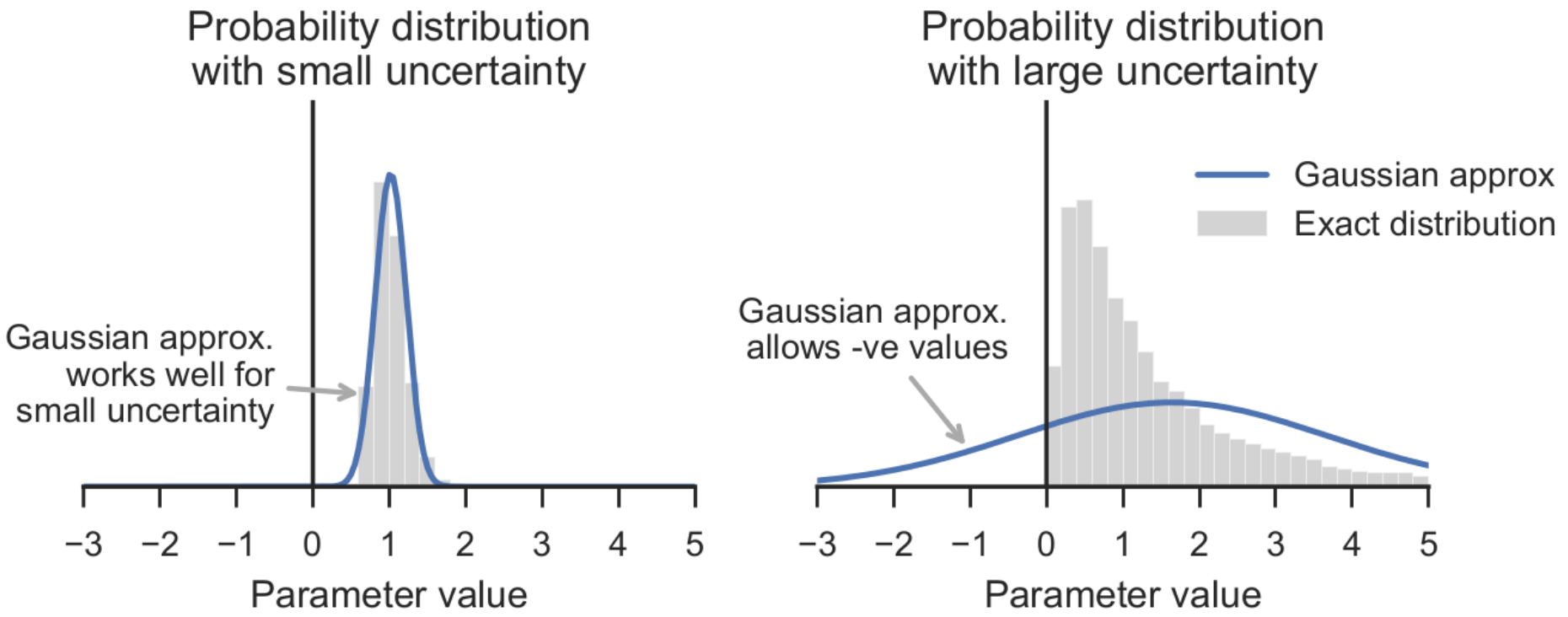
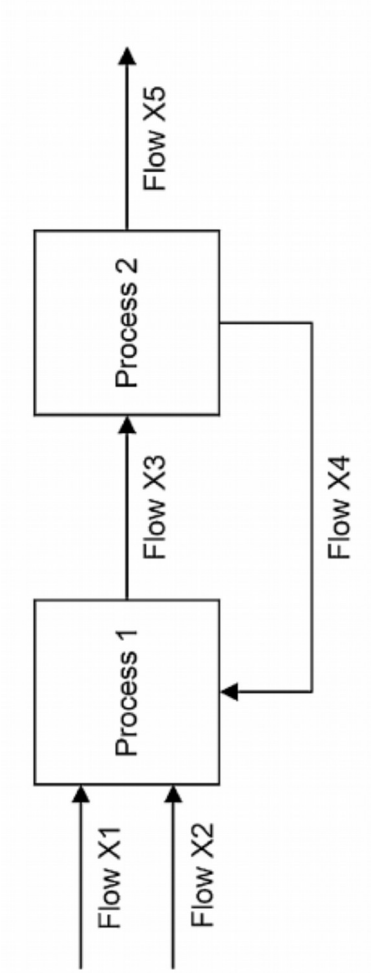
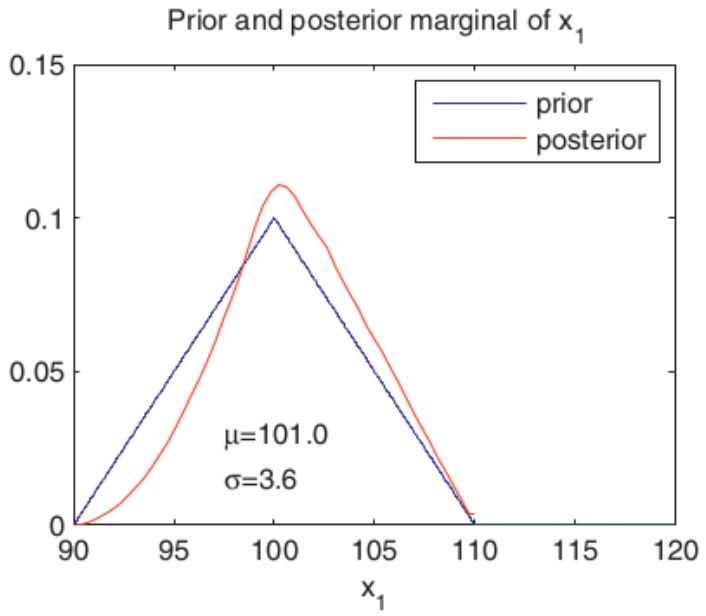
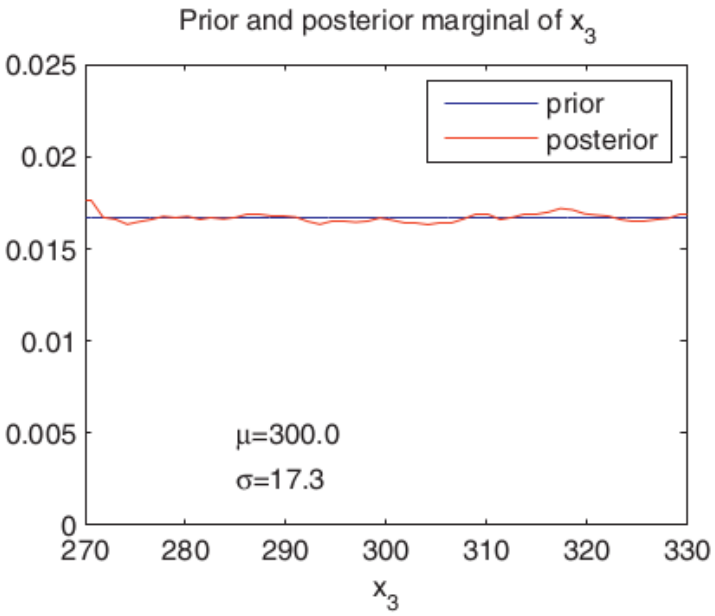


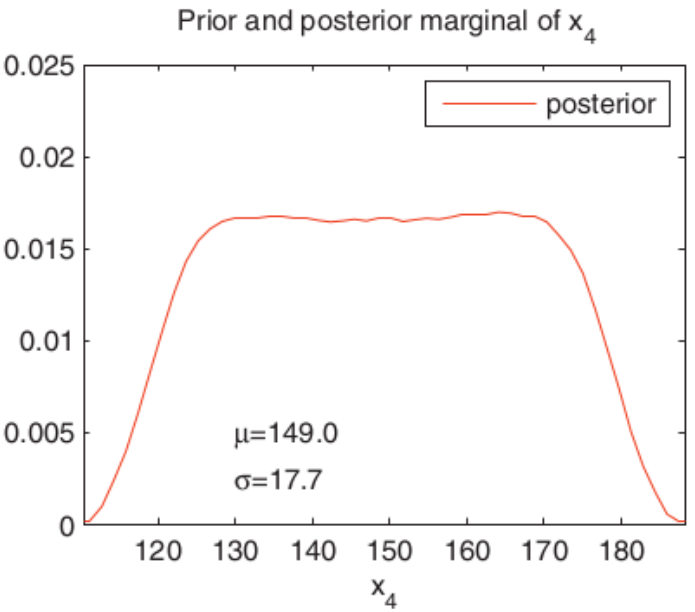

Lupton, Richard C., and Julian M. Allwood. 'Incremental Material Flow Analysis with Bayesian Inference', under review.

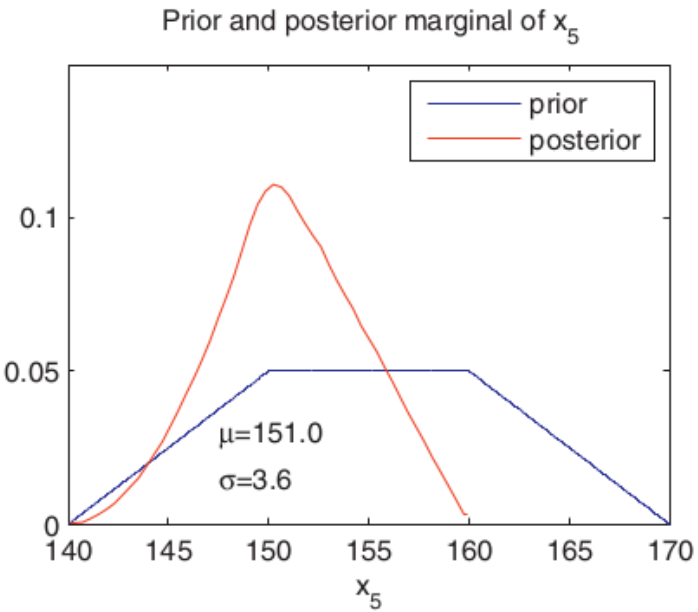
# Uncertainty as a placeholder




Cencic, Oliver, and Rudolf Frühwirth. 'A General Framework for Data Reconciliation—Part I: Linear Constraints'. Computers & Chemical Engineering 75 (2015)

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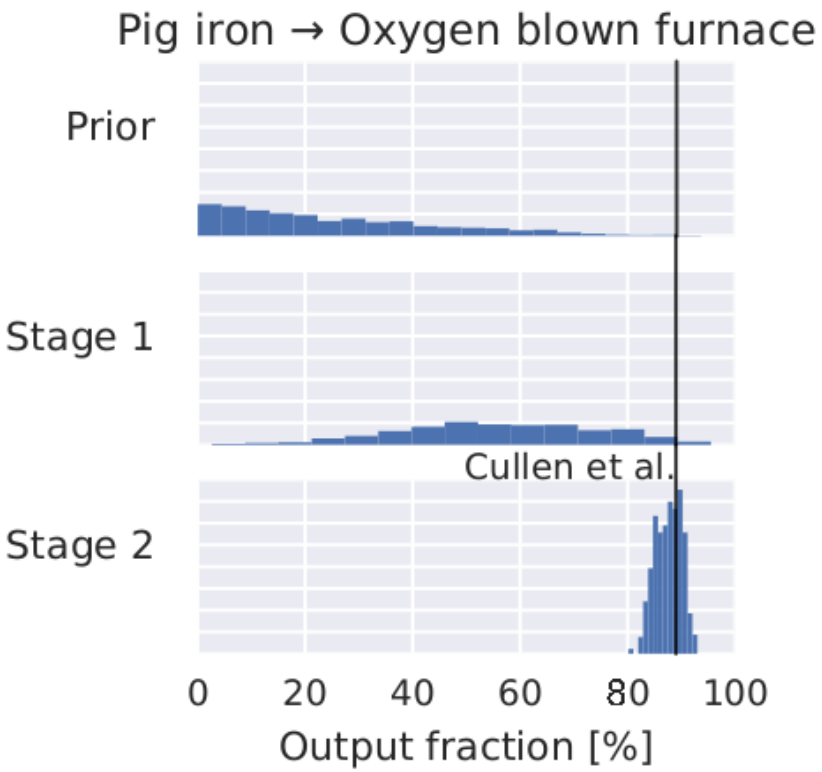


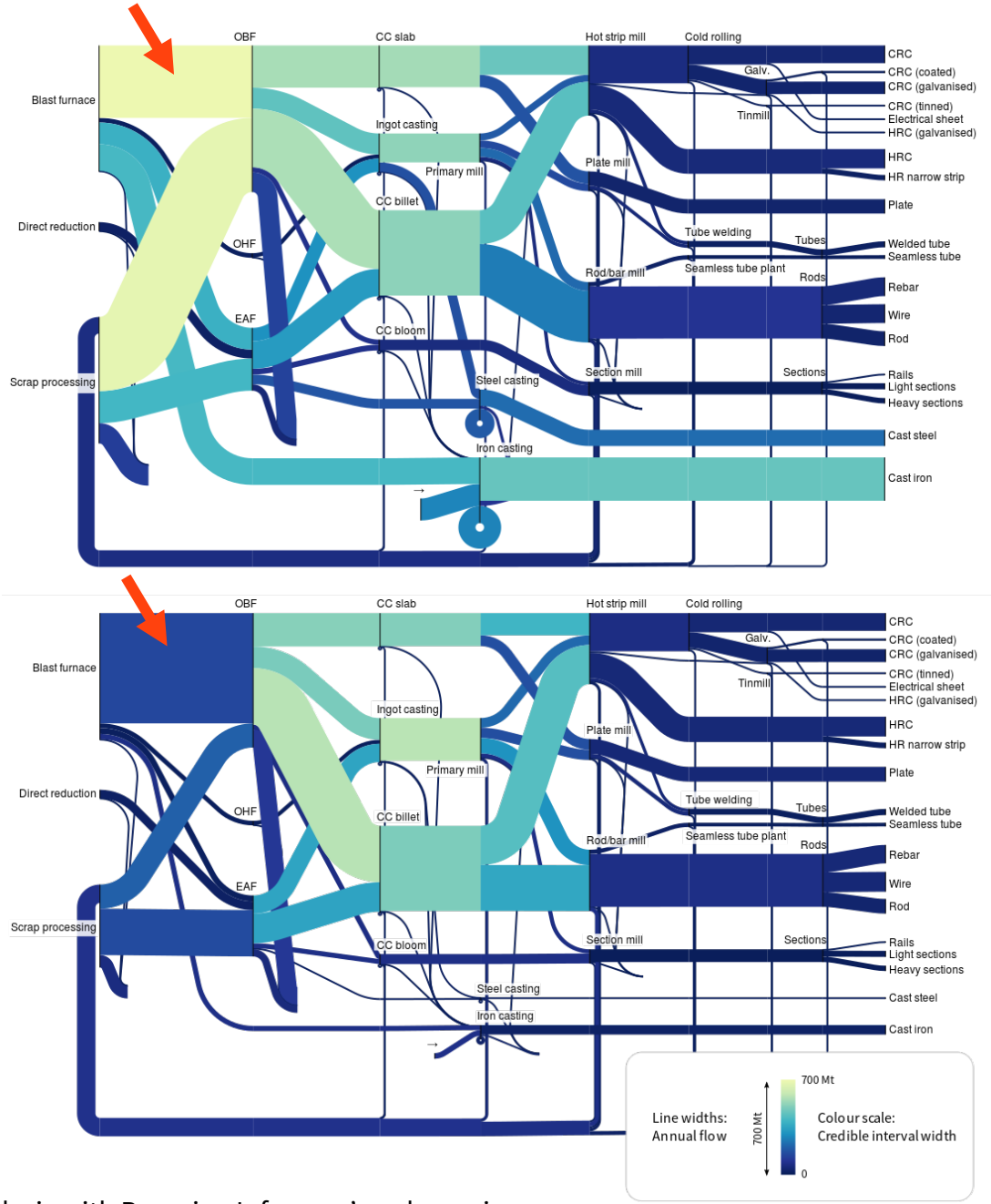


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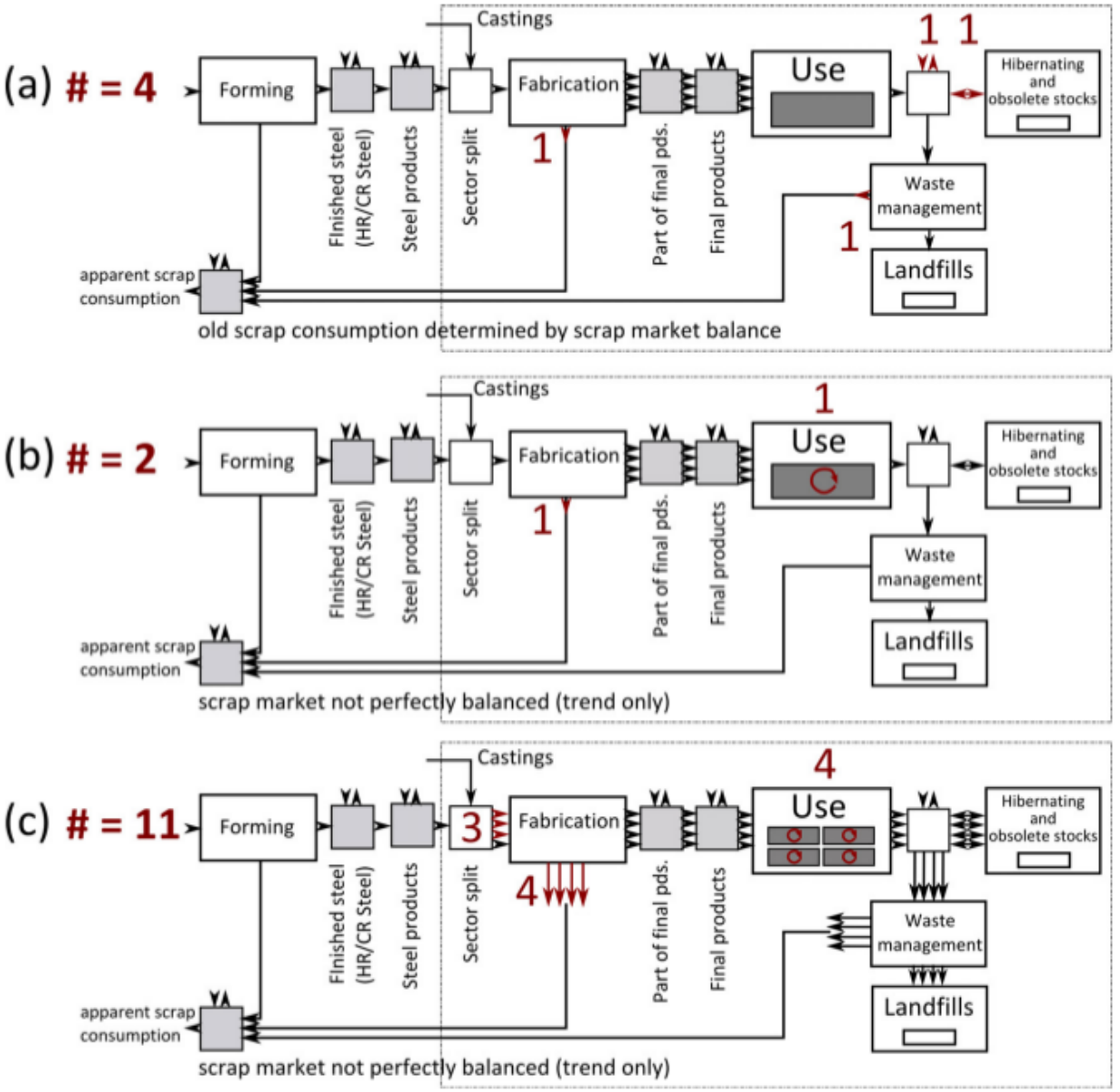
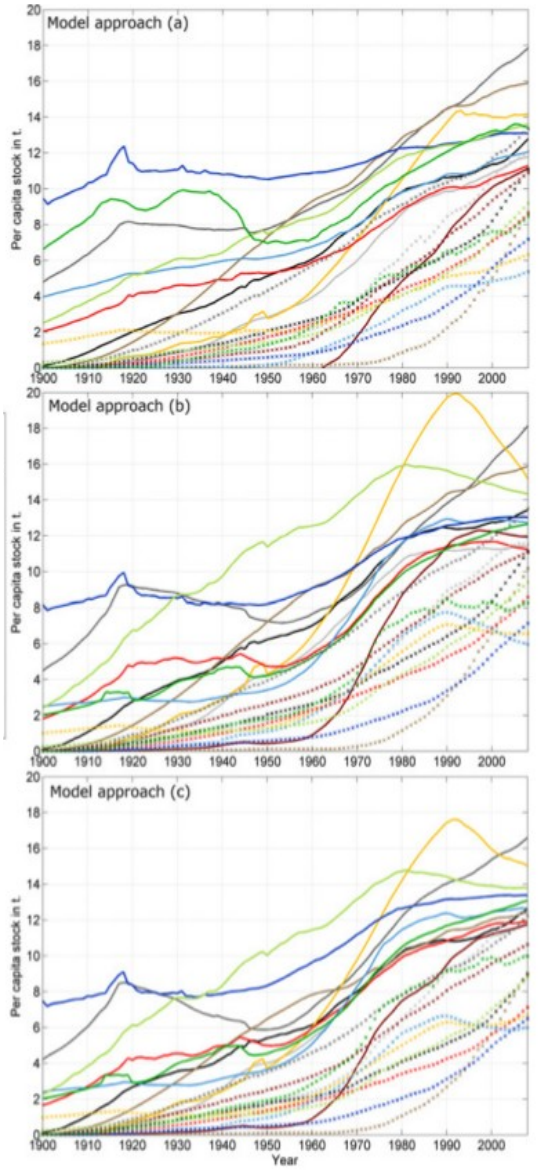
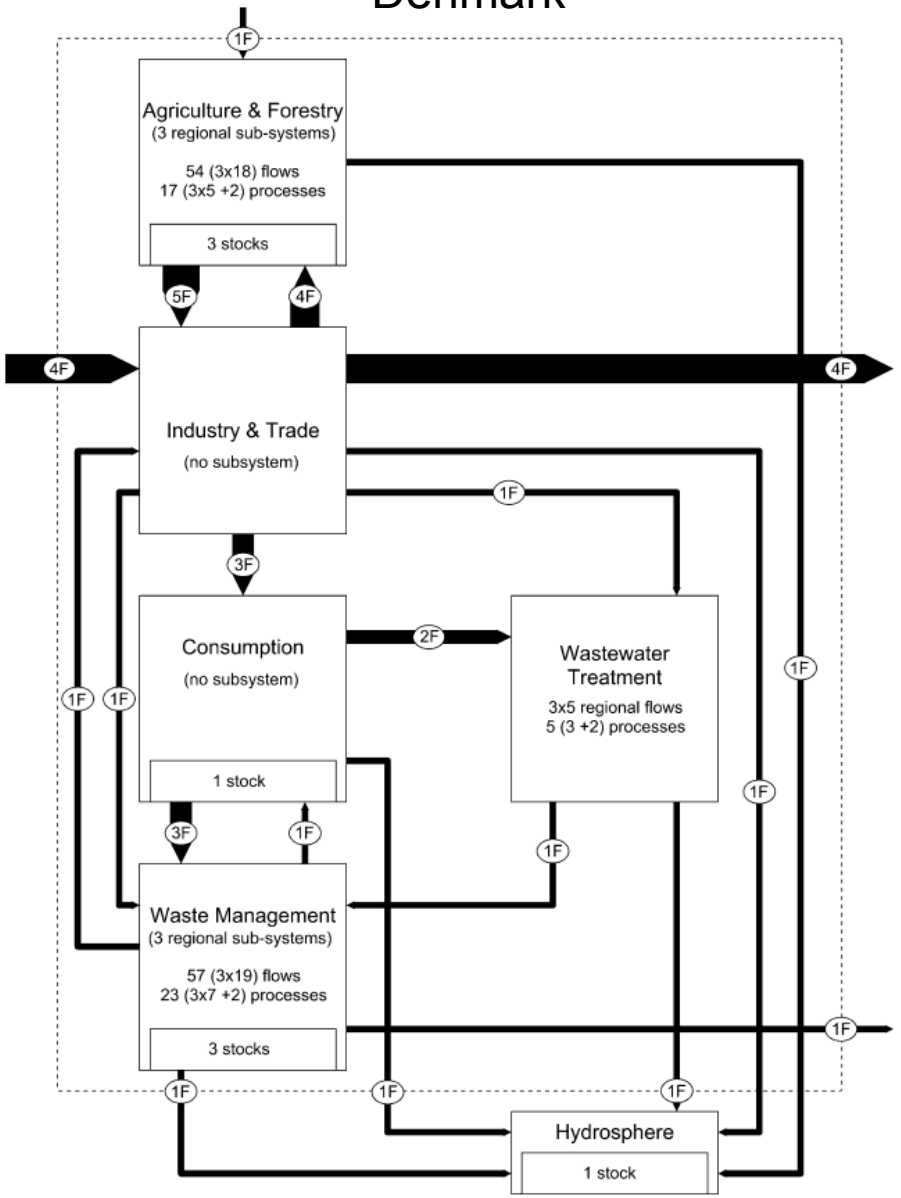


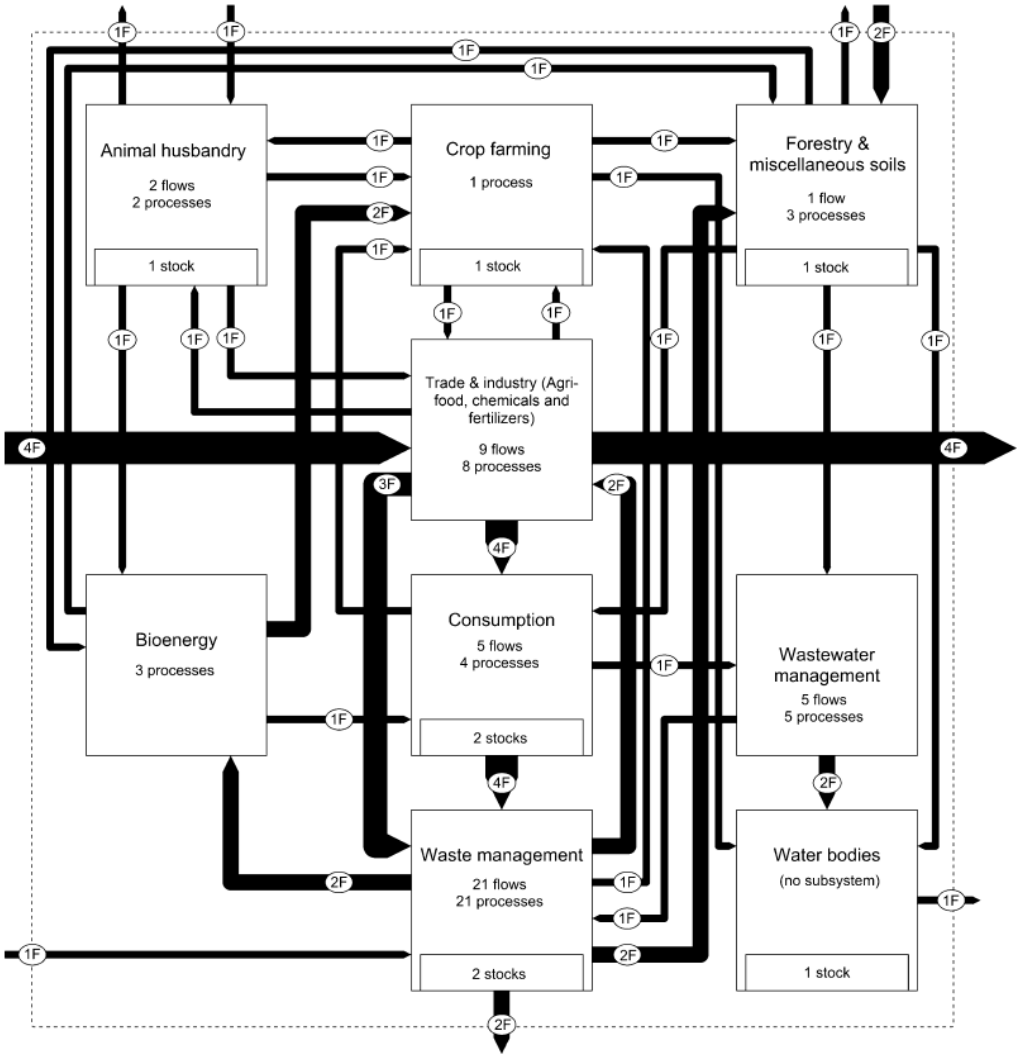

Pauliuk, Stefan, Tao Wang, and Daniel B. Müller (2013). 'Steel All over the World: Estimating in-Use Stocks of Iron for 200 Countries'.

# Model uncertainty in MFA

Denmark

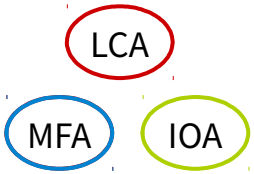



Austria




Klinglmair et al (2016). 'The Effect of Data Structure and Model Choices on MFA Results: A Comparison of Phosphorus Balances for Denmark and Austria'.

# Propagating uncertainty

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# Discussion

- Are **model** and **scenario uncertainty** sufficiently acknowledged in IE? Are better tools needed for this?
- Are current tools for uncertainty propagation sufficient, or are **new developments** needed to achieve widespread, high-quality treatment of uncertainty in IE?
- Most of these examples were about uncertainty. What about **variability**?