Sensitivity Analysis of an Energy System Model

Will Usher, UCL Energy Institute, Central House, 14 Upper Woburn Place, London, WC1H 0NN

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Introduction

The Problem

- Energy System Models are used to explore future scenarios of the energy system
- Scenarios are often defined using external sources without reference to the model
- Scenarios should highlight the *important* uncertain input parameters
- Removing the unimportant dimensions of the problem makes the analysis more efficient

Sensitivity Analysis quantifies the degree to which a model input effects an output

- Local approaches
  - e.g. one-at-a-time (OAT) approach
  - low data requirements
  - quick and easy to conduct
  - do not capture interactions between inputs
  - misleading for non-linear models
- Global approaches
  - e.g. Sobol analysis
  - often need probabilistic data
  - computationally demanding
  - capture interactions between inputs
  - handle non-linear and non-additive models

The **Method of Morris** combines the best of local and global methods

- low data requirements - only a range is required
- computationally efficient - $N(k+1)$ simulations
- output metric $\mu^\star$ compares favourably to more complex measures such as S_{t_i}

The Method of Morris

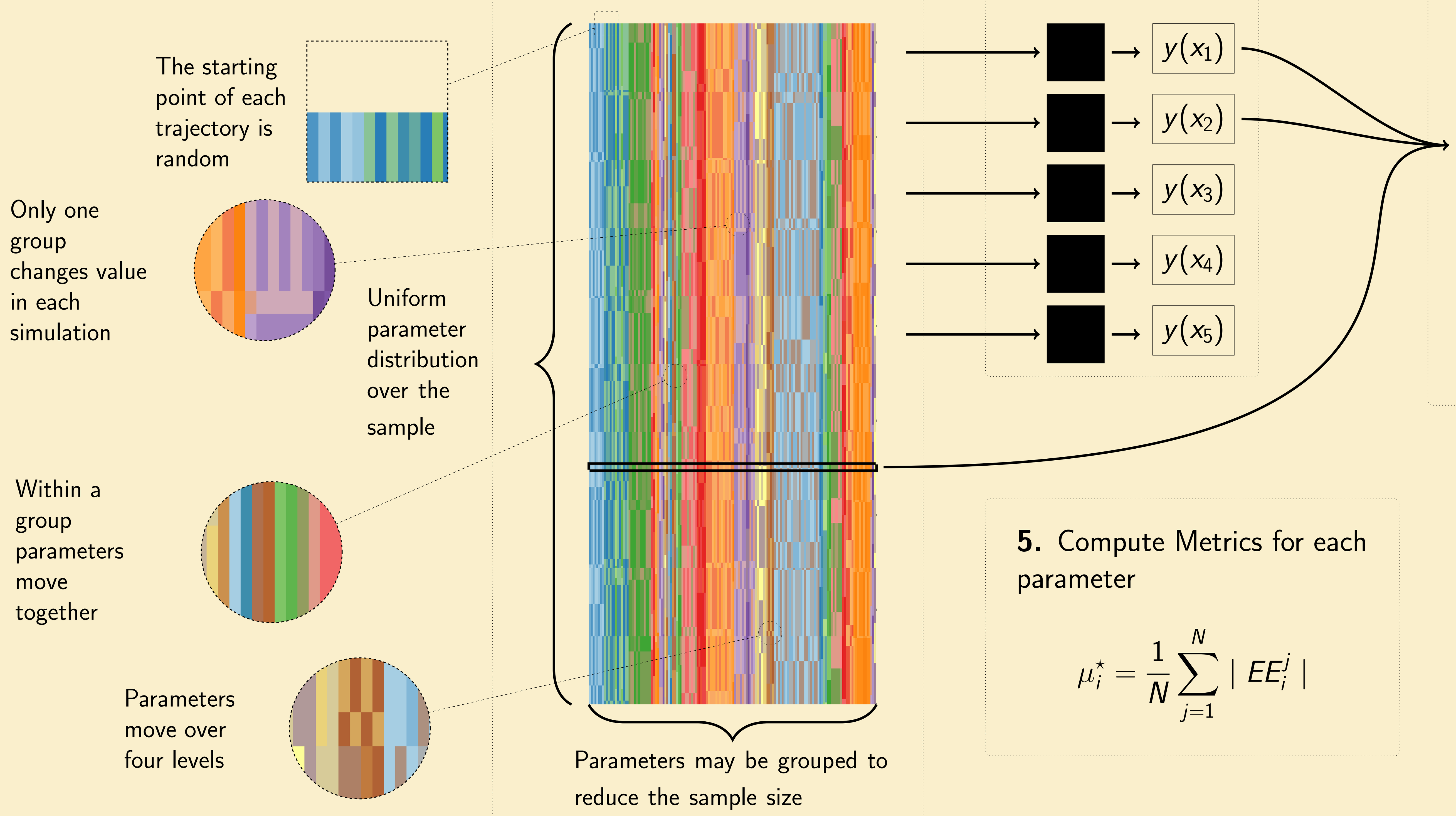
1. Define k parameters and plausible ranges

2. Generate sample

- Each column is a parameter
- Colours represent groups of parameters
- Shading represent 4 levels of a parameter

3. Run Model

for each simulation



4. Compute elementary effects

$$EE_i^j(\mathbf{x}^{(l)}) = \frac{\left[y\left(\mathbf{x}^{(l\pm1)}\right) - y\left(\mathbf{x}^{(l)}\right)\right]}{\pm\Delta},$$

$$EE_i^j = \begin{pmatrix} ee_{1,1} & ee_{1,2} & \cdots & ee_{1,j} \\ ee_{2,1} & ee_{2,2} & \cdots & ee_{2,j} \\ \vdots & \vdots & \ddots & \vdots \\ ee_{i,j} & ee_{i,2} & \cdots & ee_{i,j} \end{pmatrix}$$

Each trajectory allows the computation of one elementary effect per parameter

5. Compute Metrics for each parameter

$$\mu_i^\star = \frac{1}{N}\sum_{j=1}^{N} \mid EE_i^j \mid$$

6. Average $\mu^\star$ for each group of parameters

$$\mu_g^\star = \sum_{i=1}^{k} G_{ig} \times \mu_i^\star$$

Results

Summary of Results

- Two parameters account for the majority of the variation in carbon price
- Availability of biomass is a key determinant of supply side decarbonisation
- The build rate of carbon capture and storage technologies (CCS) is an influential factor
- There are significant non-linearities/interaction effects for the most important input parameters

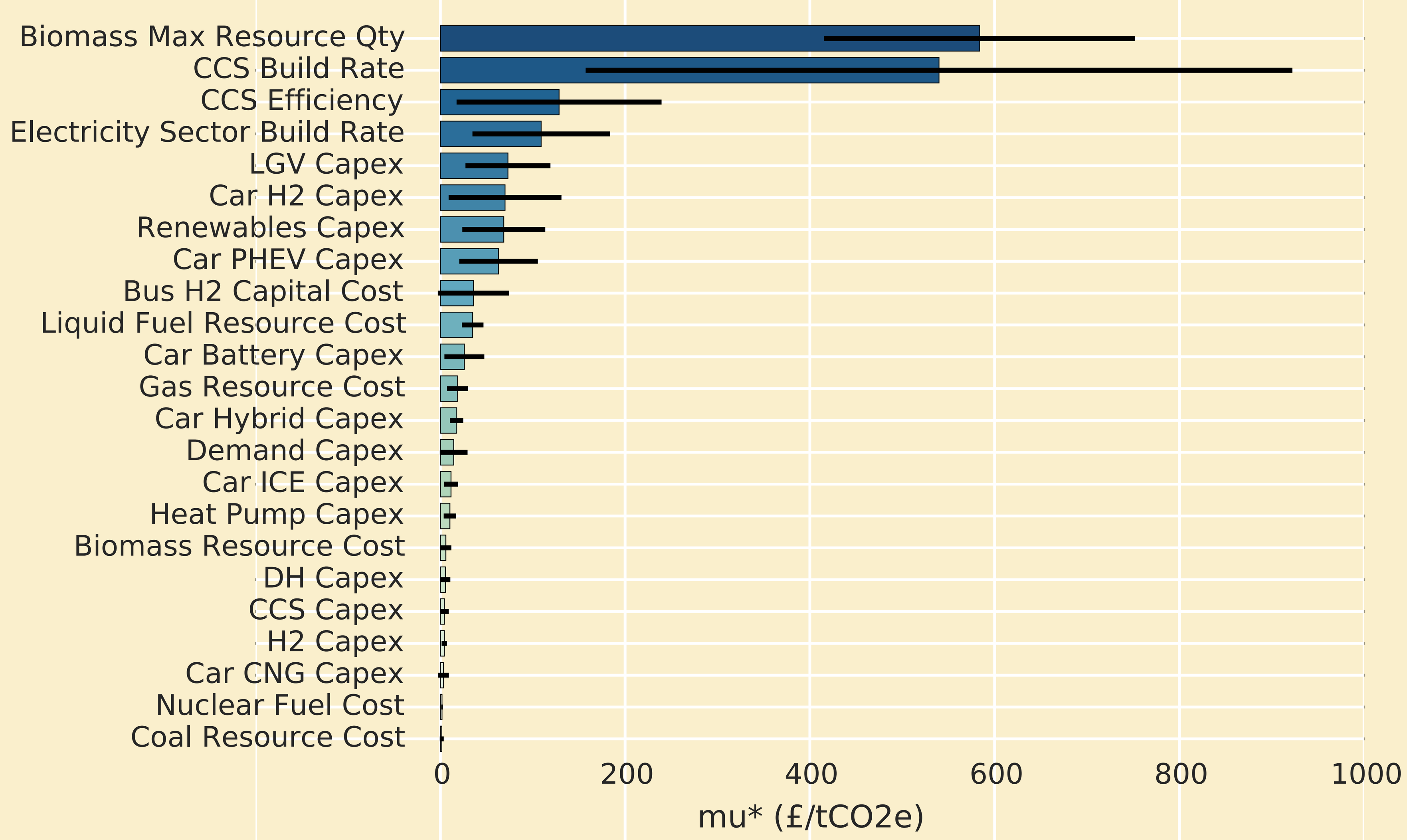


Figure: Sensitivity measure for carbon price in 2050 under an 80% GHG emission constraint

Discussion

- The Method of Morris enables us to safely exclude the majority of input parameters as important for the model results
- This reduction in model dimensionality allows model users to select just the key parameters for the scenario analysis
- This approach gives limited information about which parameters interact, and assumes input parameters are uniformly distributed and independent

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